THE USE OF ERGOGENIC AIDS IN CYCLISTS

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LIST OF ABBREVIATIONS

EPO	Erythropoietin
HGH	human growth hormone
Km	Kilometre
VO_{2max}	maximal oxygen consumption/capacity
BMX	bicycle motorcross
CHO	carbohydrates
OTS	overtraining syndrome
ATP	adenosine triphosphate
EIMD	exercise-induced muscle damage
DOMS	delayed onset muscle soreness
CNS	central nervous system
PRO	protein
NSAIDs	non-steroidal anti-inflammatory drugs
IOC	International Olympic Committee
WADA	World Anti-Doping Agency
TUE	Therapeutic Use Exemption
LOE	level of evidence
RDA	recommended daily allowance
BCAA	branched chain amino acids
ACSM	American College of Sports Medicine
COX	cyclo-oxygenase
IGF-1	insulin like growth factor one

RBC	red blood cells
rHuEPO	recombinant human erythropoietin
AAS	anabolic-androgenic steroids
CI	confidence intervals
HREC	Human Research Ethics Committee
SD	standard deviation
BMI	body mass index
URL	uniform resource locator
IP	internet protocol
SAIDS	South African Institute for Drug-Free Sport
UCI	Union Cycliste Internationale

ABSTRACT

Background

It is well known that athletes seek out ergogenic aids to enhance sporting performance. However, due to the sensitivity of the subject, it is difficult to know the extent of ergogenic aid use. An understanding of the prevalence, patterns of use and factors influencing the decision-making process amongst cyclists will help to improve prevention and educational strategies. There is little available literature documenting these characteristics in South African cyclists.

Aim and objectives

The aim of this study was to describe the use of ergogenic aids in South African cyclists during training and competition. The specific objectives of this study were to: (a) To obtain information on the use of ergogenic aids in male and female South African cyclists, with regard to the type of ergogenic aids used, and the pattern of use during training and competition; (b) To determine South African cyclists' perception of the effect of ergogenic aids; (c) To determine the sources of information influencing South African cyclists' use of ergogenic aids and (d) To explore the socio-demographic and training factors that may predict the use of ergogenic aids, such as age, level of education and training, and competition history.

Methods

This study used a descriptive correlational study design method. Participants included male and female cyclists between 18 and 65 years old. Participants that did not give informed consent and who failed to meet the training and medical screening criteria were excluded from the study. Participants were recruited through electronic correspondence, cycling clubs and cycling-specific media platforms. A self-developed questionnaire was designed to obtain information on ergogenic aid use in cyclists during training and competition, as well as to determine cyclists' pattern of use and their perceived effect of ergogenic aids. The questionnaire was available in English and Afrikaans, and explored both legal and illegal ergogenic aid use. A panel of experts reviewed and validated the questionnaire. The online questionnaire was anonymous; with all referring uniform resources (URLs) and internet protocol (IP) addresses of respondents hidden to ensure complete anonymity.

Results

The number of respondents was 467. Two hundred and seven questionnaires (n=177 males; n=30 females) were included for data analysis. Two hundred and sixty participants did not qualify for the following reasons: they did not provide informed consent, they failed to meet the training and medical screening criteria, did not use the ergogenic aids listed, and did not complete more than 30% of the questionnaire. The mean age of participants was ± 44 years. Participants used an average of three ergogenic aids. Four participants (0.8%) reported using illegal/banned ergogenic aids, which included anabolic steroids, human growth hormone, and/or cortisone.

Nutritional ergogenic aids (42.0%) were used most often, followed by pharmacological aids (23.4%) and illegal/banned ergogenic aids (0.8%). Sports drinks/gels had the highest reported use (90.8%), followed by carbohydrates and protein (56.5%), caffeine (44.9%) and electrolytes (40.1%). Most ergogenic aids (75.0%) were used for both training and competition. Non-steroidal anti-inflammatories (66.7%), analgesics (43.8%) and cortisone (100%) were most frequently used only when participants were stiff and/or injured. The most frequent perceived effect of ergogenic aids by participants (58.3%) was increased endurance and time to fatigue. Self-experimentation and fellow cyclists were influential sources of information in the decision to use certain aids. The use of reliable information resources, such as research articles was reportedly low (<12.0%), which correlated with the findings of the inappropriate use of most ergogenic aids. Age, preferred cycling event, average weekly mileage, and the amount of recovery days taken after an event, were significant factors for predicting the use of specific ergogenic aids.

Conclusion

The findings of this study suggest that the use of ergogenic aids to enhance performance occurs at all levels of cycling participation. The prevalence of use of legal ergogenic aids is high and is associated with misconceptions and inappropriate use, thus potentially risking the health of individuals. A key criterion of the World Anti-Doping Agency (WADA), South African Institute for Drug-Free Sport (SAIDS) and Cycling South Africa is the protection of the athlete' health. Therefore it is important that these regulatory and organisational authorities collaborate to promote, provide and disseminate accurate information about ergogenic aids to the cycling community. Improved and focussed educational interventions may also assist in changing behaviour and influencing safe participation in cycling.

CHAPTER 1: INTRODUCTION AND SCOPE OF THE DISSERTATION

1.1 INTRODUCTION

Cycling is a common form of exercise for athletes of all ages and its popularity has increased at both recreational and professional levels [1,2]. The sport is associated with complex physiological requirements due to interactions between high intensity and endurance exercise [1]. The demands of both training and competition push cyclists to their physical limits [3].

Cyclists continually aim to improve performance during training and competition and this has led to a shift towards the use of ergogenic aids. Nutritional, pharmacological and physiological ergogenic aids are used in an attempt to improve race performance and maximise training adaptations [4]. The use of ergogenic aids is not only limited to competitive cyclists. Illegal/banned ergogenic aids within cycling include erythropoietin (EPO), human growth hormone (HGH), anabolic steroids and cortisone [5]. Athletes misuse these substances for the pharmacological and physiological effects they have on performance [5]. The use of these substances within the sporting domain is often inaccurate in relation to means of administration and quantities used. The side effects may also be substantial, for example, the use of anabolic steroids is associated with an increased risk of cardiovascular events [5].

The consumption of ergogenic aids is common across all sporting disciplines. Amongst professional athletes there is an estimated prevalence of use of ergogenic aids ranging from 57% to 94% [6]. The type of ergogenic aids used and the pattern of use is largely sport-dependent. The highest use tends to occur in individual endurance-type sports, such as athletics and cycling [6]. It is difficult to know the extent of doping due to the sensitivity of the subject [7]. Only a handful of studies have reported the prevalence of use of ergogenic aids amongst cyclists which ranged from 10.3% to 17.5% [6-10].

To date there is very little scientific evidence supporting the performance-enhancing effects of legal ergogenic aids, as well as the safety profiles and long-term effects of both legal and illegal/banned ergogenic aids. Many of the proposed benefits are based on anecdotal data and results vary widely across studies [6,11]. As a result, ergogenic aids are often used by athletes without a full understanding of the potential benefits or risks associated with the different aids [12].

The attitudes and knowledge among cyclists towards doping and the use of ergogenic aids remain a relatively unexplored issue [6,13]. An understanding of the reasons for use and the sources of information used will assist cyclists in their choice of whether or not to use ergogenic aids [6].

Educational measures should aim to reduce the improper use of ergogenic aids. Effective anti-doping strategies within cycling should be based on the type, frequency and pattern of use of ergogenic aids [6].

However, there is a lack of evidence regarding the prevalence of use of ergogenic aids in South African cyclists. Therefore, the aim of the present investigation was to examine the use of ergogenic aids in South African cyclists during training and competition.

1.2 AIM AND OBJECTIVES

1.2.1 Aim

The aim of this study was to describe the use of ergogenic aids in South African cyclists during training and competition.

1.2.2 Specific objectives

The specific objectives were:

- To obtain information on the use of ergogenic aids in male and female South African cyclists, with regard to the type of ergogenic aids used, and the pattern of use during training and competition;
- To determine South African cyclists' perception of the effect of ergogenic aids;
- To determine the sources of information influencing South African cyclists' use of ergogenic aids;
- To explore the socio-demographic and training factors that may predict the use of ergogenic aids, such as age, level of education and training and competition history.

1.2.3 Significance of the dissertation

There is little available literature on the use of ergogenic aids in cyclists, especially in South Africa. The findings of this study may improve knowledge regarding the prevalence of use of ergogenic aids in cyclists. The identification of the practices employed and cyclists' knowledge of the mechanisms of the action of ergogenic aids is necessary to ensure safe and healthy participation in cycling. The objectives stated in Section 1.2.2 therefore need to be fully investigated to improve educational interventions regarding the use of legal ergogenic aids, and for effective doping deterrence methods to be instituted.

1.3 PLAN OF DEVELOPMENT

In preparation for the investigational phase of this dissertation, a comprehensive review of the literature on ergogenic aids commonly used by cyclists will be presented (Chapter Two). This will be followed by a descriptive questionnaire-based study designed to determine which ergogenic aids cyclists are using during training and competition (Chapter Three). Furthermore, Chapter Three will include the limitations of this study and recommendations for future research. A Summary and Conclusion (Chapter Four) will complete this dissertation.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

Participation in cycling is growing at an exponential rate each year [1,2]. Races are held in all environments and over various terrains with a three- to four month competitive season for professionals [1,3]. Cyclists may participate in competitions comprising of one-day events, multi-day events (three- to ten-days) and three-week events [3,14]. The variations in terrain, long distances and time trials demand different performance attributes from cyclists, but all these types of events push cyclists to fatigue in both training and competition [3].

Athletes exploit ergogenic aids to address the metabolic disturbances that may result from high-intensity training and competition in an attempt to improve their performance [15,16]. Ergogenic aids may be defined as "*any means of enhancing energy utilisation, including energy production, control, and efficiency*" [11]. There are five categories of ergogenic aids, namely: mechanical aids (e.g. lightweight bicycle frames); nutritional aids (e.g. protein supplementation); psychological aids (e.g. hypnosis); physiological aids (e.g. blood doping) and pharmacological aids (e.g. caffeine supplementation) [11].

Mechanical, psychological and nutritional ergogenic aids receive little media attention; nonetheless they are considered performance enhancing. Over the last few decades cycling has become synonymous with doping; where pharmacological and physiological ergogenic aids receive the most attention [17,18]. These include caffeine, EPO, blood transfusions and HGH [11,18]. There is little scientific literature documenting what cyclists are actually using and results may vary widely between studies [11]. Most evidence is anecdotal and the popularity of many substances precedes scientific validation [19]. The health of an athlete may be negatively affected by the use of ergogenic aids and therefore it is important to investigate exactly what cyclists are using [20]. To our knowledge, no study has investigated the use of ergogenic aids in South African cyclists.

This literature review will discuss the sport of cycling, cycling participation and training, fatigue and recovery from endurance exercise, with particular reference to cycling. It will present commonly used nutritional, pharmacological and physiological ergogenic aids in cyclists and examine the evidence for the performance benefits of these different aids, as well as the potential side effects. This review will not cover mechanical or psychological ergogenic aids.

PubMed, Google Scholar and EBSCOhost were searched using the following keywords: "*ergogenic aids*", "*doping*", "*drugs in sport*", "*endurance*", "*cycling*", "*prevalence*", "*South African cycling*" "*supplements*", "*performance*", "*training*", "*recovery*", "*fatigue*", "*sports drinks*", "*carbohydrates and cycling performance*", "*protein and cycling performance*", "*creatine and cycling performance*", "*amino acids and cycling performance*", "*electrolytes and cycling performance*", "*caffeine and cycling performance*", "*Vitamin B and cycling performance*", "*anti-inflammatories and cycling performance*", "*analgesics and cycling performance*", "*blood doping and cycling performance*", "*EPO and cycling performance*", "*anabolic steroids and cycling performance*", "*human growth hormone and cycling performance*" and "*corticosteroids and cycling performance*". Reference lists of all relevant studies were reviewed for additional publications. Caffeine, blood transfusions, EPO, creatine supplementation and nutrition (carbohydrates and protein) were the most researched ergogenic aids in cycling.

2.2 CYCLING AS A SPORT

2.2.1 Participation in cycling

The interest in road cycling events began near the end of the 19th century and the enthusiasm and growth for the sport continues. Well-known cycling races are viewed on television all around the world and can attract millions of spectators [(21)]. There were reported to be 3.2 million South African cycling spectators in 2009 [(2)]. The first recorded cycling race took place in Paris; 31 May 1868. A year later in 1869, the first city to city race (123 km) took place: Paris to Rouen [(21)]. Road cycling has been a part of the Olympic Games since 1896 when the Olympics first began [(21)].

Mountain biking competitions were first started in the United States of America (USA) in the early 1980s [(21)]. In the last decade, mountain biking has become increasingly popular in many parts of the world [(22)]. In the USA, mountain biking events attract nearly 40 million participants annually [(23)]. Although mountain biking participation is half that of hiking participation, its participation is reported to be far larger than any other off-road or trail activities [(23)].

Cycling was ranked as one of the top 15 sporting codes in South Africa in 2009, and the 10th most popular participation sport overall amongst Caucasians [2]. There are currently 145 registered cycling events held each year in South Africa [2]. South Africa is also home to the world's largest individually timed cycle race (Cape Argus Pick 'n Pay Cycle Tour) where approximately 35 000 cyclists compete in this mass start event [24,25]. Cross-sectional studies show that cycling provides valuable health benefits [26]. Denmark reported a 20% increase in cycling participation from 1996 to 2002 and an increased life expectancy of five months for males [26].

In 2009 there were approximately 526,900 South Africans participating in cycling [2]. A 7.7% growth rate in cycling participation was reported from 2008 to 2009 [2]. Cycling South Africa recently reported a 55.6% increase in licensed members from 2012 to 2013 [2]. This positive growth trend in cycling participation therefore warrants more concern about the health risks associated with the use of ergogenic aids [11].

2.2.2 The disciplines within cycling

Cycling offers a diverse nature of events; however, it is largely an endurance sport [6]. It requires extreme physiological and metabolic demands of the body [17,27]. Passfield and Doust[28] showed that as little as five minutes of cycling correlated strongly to maximal aerobic power (VO_{2max}). There are five major disciplines within the sport supported by Cycling South Africa, namely: road, mountain biking, track, bicycle motorcross (BMX) and para-cycling [2]. Endurance cycling, both on-road and off-road is regarded as strenuous exercise, with the Tour de France being one of the toughest, if not the toughest sporting competition [17,27]. This review will focus on road cycling and mountain biking.

Road cycling has a mass start in which all the participants start together in a bunch [21]. There are several road racing formats that may include; point-to-point cycling, circuit route cycling or stage race cycling [21]. In a professional road cycling season there may be 90 to 100 competition days [3]. Races vary between one day, one week or three weeks in length, with stage distances varying from 5 km to 300 km [3,29]. A professional cyclist may cover a distance of 35 000 km a year [27]. An amateur cycling season, on the other hand, typically consists of 50 competition days, with races not normally exceeding two-days [1]. An amateur cyclist may cycle up to 25 000 km a year [1].

Competition requirements for both professional and amateur cyclists may include long, flat stages; mountainous ascents and time trials [3]. There may be individual or group time trials depending on the race format. Time trials are generally raced over a 40 km to 50 km distance, where cyclists set off individually at regular intervals of one to two minutes [21]. The participant with the fastest time is the winner. Team time trials are similar to individual time trials with a minimum of two cyclists and a maximum of ten cyclists per team [21].

Mountain biking events can either be held over short (five to nine kilometres), undulating circuits which are a part of the Olympic programme or longer mountainous marathon versions (60 km to 120 km) [21]. The various terrains include steep ascents, technical descents, rocky paths and obstacles [21]. Cyclists of all calibre start together in the longer mountain biking events, whereas the short circuit events are generally for more advanced cyclists [21].

Power output when climbing uphill in both disciplines is directly influenced by the weight of the cyclist and their bicycle. As a result, cyclists specialising in climbing mountainous terrain try to be as light and as lean as possible [1]. Outdoor training and competitive events may present a variety of factors which cyclists need to overcome to maintain maximum power output and peak performance. The physiological demands of competitive cycling need to be determined so that training strategies and performance can be optimised [14].

2.3 TRAINING FOR ENDURANCE CYCLING

2.3.1 Physiological adaptations to endurance cycling training

An improvement in exercise capacity is underpinned by the ability of skeletal muscle to adapt to repetitive bouts of exercise training [3,30]. Physiological events that occur after exercise may be the stimulus for chronic adaptations to training [30]. A multitude of adaptions occur in many physiological systems (muscular, cardiovascular and endocrine) as a result of endurance cycling [31]. It is well-documented that endurance training leads to an increase in the number of capillaries in muscles, thereby increasing the amount of oxygen delivered to the muscles to maximise endurance performance [31]. The extent of any adaptation as a result of physical training is directly related to the overall training stimulus [31]. These training adaptations are summarised in Figure 2.1.

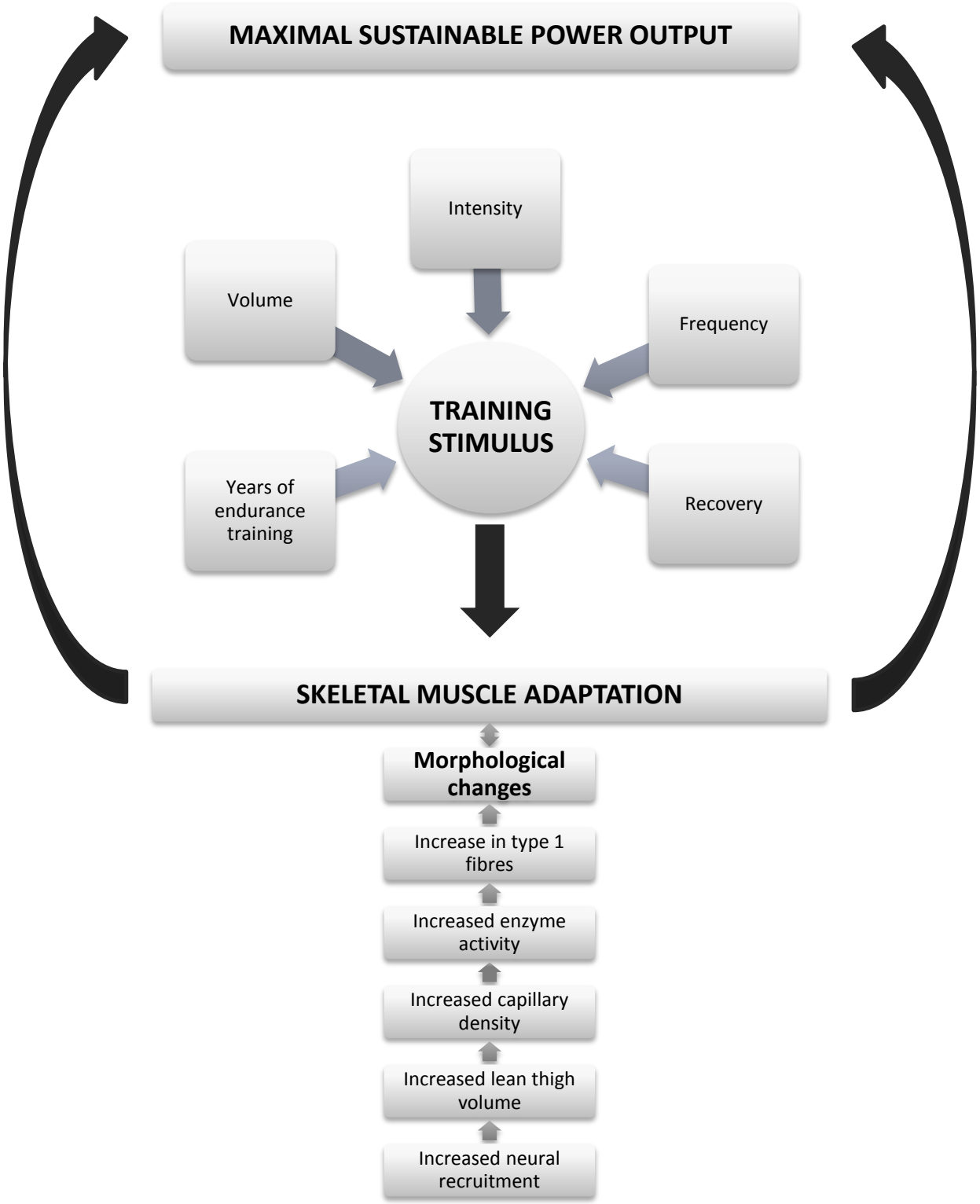

Figure 2.1: Magnitude of skeletal muscle adaptation is directly related to the training stimulus; and the skeletal muscle adaptations influence endurance performance ability (adapted from Hawley and Septo, 2001[31]).

Physiological factors influencing a cyclist's ability and performance include the individual's VO_{2max}, muscle fibre type, muscle capillarisation and cycling efficiency [1,32]. Research has shown that endurance athletes have a high VO_{2max}, which is consistent with observations seen in professional cyclists [1]. A professional cyclist's relative VO_{2max} is typically in the range of 70 $ml.kg^{-1}.min^{-1}$ to 85 $ml.kg^{-1}.min^{-1}$ [1,33,34]. This is high in comparison to the average VO_{2max} (43 $ml.kg^{-1}.min^{-1}$) for healthy individuals [34]. Studies have shown that the VO_{2max} for amateur cyclists are very similar to professionals, however the difference is in their power output achieved at VO_{2max} [1].

Physiologically, an athlete with a high proportion of type 1 muscle fibres has the ability to sustain high power outputs over a prolonged period of time, thus making them a good candidate for endurance cycling [1]. A greater gross efficiency (lower submaximal oxygen costs) during cycling has been associated with a high proportion of type 1 fibres in the vastus lateralis muscle [35]. The number of type 1 fibres in the vastus lateralis muscle of cyclists is highly related to the number of years spent performing endurance cycling [31]. The literature also highlights the importance of muscle capillarisation for endurance sports [1,31]. A high density of capillaries allows for an abundant supply of both oxygen and nutrients to sustain the large energy output requirements [1]. Specific studies on cycling performance and capillarisation are limited. However, Coyle et al[36] found a high correlation (r=0.74) between capillary density and time to fatigue. Neuromuscular recruitment also improves in response to sport-specific training patterns [31]. After a bout of short-term resistance training the observed improvements in dynamic muscular strength are attributed to better neuromuscular recruitment patterns rather than increases in muscle fibre size [31]. Collectively these training-induced neuromuscular adaptations enable cyclists to recruit more muscle fibres, therefore producing power over a larger active muscle mass while pedalling [31].

Another training adaptation that enhances endurance cycling performance is that highly trained (professional and amateur) cyclists oxidise less carbohydrates (CHO) and more fat compared to less well-trained (recreational) cyclists at the same absolute intensity [31]. This shift in substrate selection by the working muscles may play a major role in enhancing endurance capacity. As discussed later in Section 2.4 (page 11), the depletion of endogenous carbohydrate stores (a major fuel source during exercise) may be linked to fatigue during prolonged cycling [27,31]. All of these training-induced adaptations of skeletal muscle can improve a cyclist's performance capacity; however, all are a result of high-volume, high-intensity training [18]. Please refer to detailed reviews by Hawley and Septo (2001)[31] and Coyle et al (1991)[37], as further discussion of training adaptations is beyond the scope of this dissertation.

Power output during a cycling race is not only influenced by innate physiological ability, but also by positioning of the cyclist on the bike, pacing strategies, training and nutrition [1,38]. Competitive cycling is thus characterised by the interrelationship between all of these factors [1].

2.3.2 Important components of endurance cycling training

Many studies have investigated the benefits of training on performance [3,30,31,37,39]. However, the majority of these studies have used untrained individuals. Untrained individuals have large improvements in VO_{2max} after a training programme, whereas highly trained individuals show smaller improvements after training [39]. There is not much literature describing the effects of additional training on elite athletes, especially cyclists [39].

The goal of endurance training in cycling is to maintain a high average power output over a prolonged distance and time [3,30]. The volume (how many minutes or hours in a session per day), frequency (how many training sessions per week) and intensity of exercise sessions, are all important components of training programmes. Improved performance or decreased performance (fatigue) can be directly related to the sum of these training variables [30].

To reach an overload in training stimulus, cyclists will generally increase training volume and frequency. When overload can no longer be induced with increases in volume and frequency, interval training will be employed [27,40]. High-intensity intermittent training (interval training) has been shown to improve maximum short-term power output, VO_{2max} and both glycolytic and oxidative enzyme activity [27,31]. Interval training lasting only 30 seconds, at 175% of peak power, with four-and-a-half minutes recovery, repeated 12 times, was just as effective as improving in a 40 km time trial, as was four-minute bouts of interval training [27]. The underlying mechanisms of the efficiency of this type of short-term, high-intensity training, is the increased ability of the cyclist to sustain a higher fraction of VO_{2max} or power output for a longer period of time, due to an improved muscle buffering capacity [27]. The 40 km time trial induced in the laboratory is highly reproducible in trained cyclists, and is thus often used to test the efficacy of training protocols [27]. The average amount of power output that can be maintained in one hour is the best predictor of a 40 km time trial performance [27].

In summary, cyclists wanting to increase overall training stimulus should start by increasing training volume and frequency [27]. Training volume and frequency require a large amount of free time [40]. For the recreational and amateur cyclists, free time may be limited due to work commitments and societal pressures. On the other hand, although professional cyclists have the time to train, improvements in performance are minor and harder to achieve [39].

These factors, although different across competitive levels, may conjure curiosity in the use of ergogenic aids. Consideration of the potential factors limiting training and natural performance enhancement may suggest that the use of ergogenic aids is not only limited to professional cyclists.

2.3.3 Training implications for endurance cyclists

Cyclists often train every day, or are involved in multi-day events. Strategic development of training schedules is required to achieve peak performance. Too much cycling, combined with too little rest and recovery, may lead to overtraining. Overtraining causes tissue breakdown and a decline in performance, as well as an increased risk of injury [15,41]. The lack of recovery or incomplete recovery between successive training sessions and competition may result in cyclists being unable to continue to train at full capacity and at the required intensity [15,27,41-43]. If the balance between training and recovery is not corrected, the "*overtraining syndrome*" (OTS) may develop [27].

The OTS may manifest in both physiological and psychological symptoms, representing the point at which an athlete has surpassed their capacity to exercise (chronic fatigue) [27,44]. Decreased performance which may last months, irritability, lack of motivation and sleeping problems may develop [27,44]. Heart rate is commonly used to monitor cyclists, as it is one of the most sensitive indicators of training status [27]. Lucia et al[45] found that a decrease in maximum heart rate was the best marker indicating fatigue over a three-week cycling race. To treat OTS, the factors which lead to over-training in both activities of daily living and training must be eliminated [27]. Rest, sleep and the quality and quantity of nutrition are all important components of healing [27].

In summary if training and recovery are not balanced, the OTS may develop leading to performance incompetence [27]. Cyclists train hard to achieve peak performance and often there is the misconception that a reduction in training may cause de-training and decreased exercise performance [40]. Cyclists therefore look towards ergogenic aids to maximise training and minimise recovery time while maintaining positive increases in performance capacity.

2.4 FATIGUE IN CYCLING

It is important for both cyclists and coaches to understand fatigue and the factors determining cycling performance and fatigue. If these factors can be identified, training adaptations which are most important for improving performance can be exploited and training structures can be implemented to maximise those adaptations [3,39].

Abbiss and Laursen[3] define fatigue as "*sensations of tiredness and associated decrements in muscular performance and function*". In cycling terms, fatigue can be described as the inability to maintain an expected or required power output [27]. As a result, fatigue is generally viewed as a negative effect of exercise as it often results in reduced function and performance [46]. On the other hand, Kay et al[47] advocates that fatigue can be viewed as a safety mechanism, which is modulated by peripheral and central input, causing a decrease in exercise intensity or complete cessation of exercise to prevent injury [47].

Controversy exists in the literature as to what exactly causes fatigue [3]. Various models have been developed by several researchers, majority of which explain a linear approach to the underlying mechanisms of fatigue. The seven linear cause-effect models that have been reviewed by Abbiss and Laursen[3] include: cardiovascular fatigue, energy supply/depletion, neuromuscular fatigue, muscle trauma, biomechanical fatigue, thermoregulatory fatigue, psychological fatigue and the central governor model of fatigue. Recently a more complex non-linear model has been developed, namely the complex systems model of fatigue [3]. The different models will be briefly described in this section, as the nature of fatigue experienced by cyclists may influence the use of ergogenic aids. Please refer to a detailed review by Noakes[48] as a thorough discussion of the different models of fatigue is beyond the scope of this review.

The cardiovascular model suggests that fatigue is due to the heart's inability to supply an adequate and efficient amount of oxygen to the working muscles, as well as to remove waste products from the working muscles [3]. The energy supply/energy depletion model may be divided into two parts. Firstly it states that fatigue may be due to the failure to supply enough adenosine triphosphate (ATP) to the working muscles (energy supply). Secondly, it states that fatigue is a result of a depletion of fuel substrate in the form of muscle and liver glycogen, blood glucose and phosphocreatine (energy depletion) [3]. This theory is criticised as ATP levels hardly ever reach below 40% even after exercise to exhaustion, and in such instances, levels lower than 40% would cause rigor mortis [3,41].

The neuromuscular fatigue model is based on muscle excitation, recruitment and contraction mechanisms limiting performance. There are three viewpoints which explain where along the neuromuscular pathway inhibition may occur. There may be reduced central activation, causing a reduction in neural drive. Alternatively, there may be reduced responsiveness of the muscle to incoming stimuli. Finally, fatigue may result because of changes in the muscle affecting excitation-contraction coupling mechanisms [3]. During prolonged cycling the combination of central and peripheral alterations cause an increased perception of effort, although force and power production have decreased [3]. Exercise-induced muscle damage (EIMD) can cause a number of unfavourable effects, which are grouped under the muscle trauma model of fatigue [3].

Exercise-induced muscle damage can be classified into three groups, namely: Type 1: muscle swelling, stiffness and delayed onset muscle soreness (DOMS), Type 2: tears in the muscle fibre, and Type 3: muscle cramps/pain during exercise or on cessation of exercise [3]. Endurance cyclists tend to push high gears over extended periods of time, and therefore some form of EIMD, on the spectrum from Type 1 to Type 3 can be expected [3].

The biomechanical model of fatigue underlines the efficiency of movement on the bicycle. The less efficient movement is the more energy is expended, resulting in reduced economy and early onset of fatigue [3]. The thermoregulatory model looks at the influence of body temperature. It states that once a critical core body temperature has been reached, exercise capacity is reduced [3]. The psychological/motivational model, associates fatigue with a reduced central drive due to lower motivation and/or interest for the exercise task itself, resulting in an increase in perceived exertion [5]. Lastly, the Central Governor theory proposes that there is a regulator/governor situated in the central nervous system (CNS) which alters exercise intensity and performance according feedback from muscles and other organs [3].

However, cycling performance is not limited by one linear model of fatigue, but rather by the interaction of several different models [3]. The complex systems model of fatigue is a recent model described by Lambert et al[49] and St Clair Gibson and Noakes[50]. This model states that exercise performance is influenced and limited by a number of the linear models described above [3]. The interactions between numerous physiological systems manipulate exercise performance through continuous feed-forward and feedback loops [3]. The brain unconsciously integrates all peripheral feedback and manipulates exercise intensity and pacing strategies, allowing cyclists to finish exercise bouts efficiently without pushing one peripheral system out of homeostasis [3].

Cycling performance is determined by the ability of the cyclist to resist fatigue [3]. Coaches, cyclists and athletes are always looking for ways in which to further improve exercise performance [3]. Understanding the different models of fatigue during prolonged cycling may help to understand the use of specific ergogenic aids among cyclists. There are many influences to consider in cycling performance [1]. After a bout of intensive exercise in which cyclists have pushed themselves to near exhaustion, it is important to recover by replenishing losses and restoring homeostasis in the body. Maximising glycogen re-synthesis and minimising protein breakdown will help enhance subsequent cycling performance [1].

2.5 RECOVERY FROM TRAINING AND COMPETITION

Hard training must be balanced with the correct amount of recovery [27]. Recovery is multi-dimensional and factors related to age, gender, experience, environment and psychological well-being can influence the rate of recovery [15]. Recovery is a process whereby the muscles return to their pre-exercise state following exercise [51]. It may also be defined as the time between successive workouts or competitions [41]. During this period the goal is to maintain the physiological adaptations attained during training and competition, and minimise the negative impact of training and competition [40]. Recovery should form a key component of any successful training programme. Recovery is often overlooked due to fear of losing out on training time; however optimal performance necessitates full and optimal recovery [15,41].

The physical and physiological stress of high-intensity training and competition may provisionally impair an athlete's performance [15]. Therefore it is important that both cyclists and coaches understand the mechanisms that cause or contribute to fatigue [41]. These impairments may last for minutes, hours or even several days [15]. Impairments resulting from metabolic disturbances, glycogen depletion and dehydration after bouts of intensive exercise are normally short term (hours). Impairments that are longer-lasting and exceed 24-hours may be related to DOMS, inflammation and EIMD [15,30,43].

If the rate and quality of recovery was improved, much larger training volumes would be possible [41]. Nutritional intake and "*specialised*" modalities are also said to influence the rate of recovery [41]. Anecdotally, athletes use ergogenic aids to enhance recovery, with the goal of improving the ability to train and compete when fatigued, or to facilitate a more rapid return to training after competition. At present, there is very little conclusive literature on the efficacy of recovery modalities. Most evidence is based on anecdotal data or previous studies which have poor methodologies and the results vary widely [15]. There are a number of different recovery modalities used by athletes during training and competition [15,52]. They may include passive recovery (rest and relaxation), active recovery, massage, cold/contrast water immersion, stretching, compression garments, and a combination of the above [15,52]. Please refer to a detailed review by Barnett (2006)[15], as a detailed review of the specific modalities is beyond the scope of this current review.

The ability of an athlete to withstand intensive training and continually enhance competition performance without yielding to injury, illness, fatigue and the OTS may be influenced by nutritional intake. A normal diet is often not considered as adequate by many athletes for optimal performance [12]. Thus athletes may use ergogenic aids in an attempt to improve their diet and gain a competitive edge [12].

2.6 ERGOGENIC AIDS

2.6.1 Definition of ergogenic aids

When considering the factors that determine performance such as innate physiological ability, training and motivation, diet may be seen as only one of these factors. The use of specific food sources, vitamins and medications, for example, cannot compensate for poor training or lack of training on the part of the athlete, yet they may enhance a talented, competitive and motivated athlete to finish well [12,53].

Ergogenic aids are substances used to enhance athletic performance [13]. Ergogenic aids may facilitate sports performance and competition by enhancing physiological processes, depressing psychological inhibition and improving exercise capacity [13]. A trend in the current literature revealed that the mostly frequently used ergogenic aids amongst athletes are vitamins, amino acids, creatine, CHO and sports drinks [12,53-59]. The most commonly reported ergogenic aids used by cyclists include sports drinks, vitamins, amino acids, caffeine, protein (PRO) and non-steroidal anti-inflammatory drugs (NSAIDs) [6,57].

As stated earlier in Section 2.1 (page 4) there are five categories of ergogenic aids, and this review will focus only on the nutritional, pharmacological and physiological aids [11,18]. Research on ergogenic aids is often contradictory [13]. Substances are categorised differently across studies, making it difficult to compare findings and infer relationships and usage patterns [11,13]. Considering the popular ergogenic aids reported to be used by cyclists in the literature, and anecdotal evidence of use amongst cyclists, the substances were categorised in the following way for the purpose of this review [11,18]. Nutritional ergogenic aids included sports drinks/gels, CHO, PRO, amino acids, creatine and electrolytes. Pharmacological ergogenic aids included caffeine, vitamin supplementation, NSAIDs, analgesics, cortisone and HGH. The physiological ergogenic aids included blood transfusions, EPO and anabolic steroids [11,13]. Furthermore, all ergogenic aids may be classified as either legal or illegal/banned substances [13].

2.6.2 Classification of ergogenic aids

In 1960 the International Olympic Committee (IOC) established a Medical Commission to combat the use of drugs in sport. A list of banned substance classes and methods was then published by the IOC in 1967 [60,61]. At first, the list contained only substances which could be tested in laboratories. However, at the 1984 Olympic Games, a group of cyclists underwent blood transfusions. Blood doping was not banned at that time, as there was no formal detectable test [61].

This incident, which was later uncovered, led to the banned list including all drugs and doping methods, even if detection tests were not yet available [61]. The incidence of doping in sports continued to increase internationally and became a major health concern. In 1999, an international committee called the World Anti-Doping Agency (WADA) was formed with the goal of reducing the use of drugs in sport. After working with the IOC, WADA published a list of banned substances in 2004, supported by scientific trials and literature [60,61].

The list of banned substances published by WADA is updated yearly following an extensive consultation process, and is easily accessible online (http://www.wada-ama.org/en/Science-Medicine/Prohibited-List/) [62,63]. For a substance to be placed on the list, the substance or the method must meet two of three criteria, namely: the method and/or substance can improve athletic performance; it poses a risk to health; and/or its use violates the principle of fairness in sport [63]. Substances that are not found on the banned list (for example, caffeine and creatine), but which have an ergogenic effect, do not constitute doping [63]. Caffeine, which was once on the banned list, is now on the WADA Monitoring Programme to assess its misuse in sport [63].

WADA defines doping as "*the occurrence of one or more of the anti-doping rule violations set forth in Article 2.1 through Article 2.8 of the WADA Code*" [62]. It is the athlete's responsibility to know which of the substances and methods have been included on the banned list for cycling, and what constitutes an anti-doping rule violation. The anti-doping rule violations can be found in the WADA anti-doping code available at http://www.wada-ama.org/Documents/World_Anti-Doping_Program/WADP-The-Code/WADA_Anti-Doping_CODE_2009_EN.pdf [62].

The illegal/banned ergogenic aids and those substances requiring Therapeutic Use Exemption certificates (TUE) in this review include blood doping in the form of blood transfusions, EPO, HGH, anabolic steroids and corticosteroids [13].

2.7 ERGOGENIC AIDS AND CYCLING

2.7.1 Prevalence of ergogenic aid use in cycling

The consumption of ergogenic aids is common in sports. The estimated prevalence of the use of ergogenic aids amongst athletes ranges from 46% to 100% [6,53,55,64]. The use of ergogenic aids is sport-dependent, with the highest prevalence occurring in endurance sports, such as athletics, rowing and cycling [6]. Athletes participating in individual sports are also more likely to consume ergogenic aids in comparison to team sport athletes [26,55].

Whilst the sport of cycling continues to grow, so does the competitive nature of the sport itself [13,27]. The incidence of doping continues to increase, presenting a poor picture of top-of-the-range athletic performance [65]. The common practice of doping amongst cyclists was brought to the fore recently following confessions by professional cyclists in the media [9]. However, there has been a reduction in team doping since the last scandal, and it is now considered as a practice undertaken by certain individuals [9]. The use of banned substances to accentuate physique and performance is not only limited to the competitive cycling world. It must be recognized that athletes at a recreational level are also exploring and using a variety of ergogenic aid products [66].

Laure[10] by means of a questionnaire-based study, found a doping incidence of 17.5% in national and international cycling competitions, and a 10.3% incidence in local cycling competitions. Lenillan and Carstairs[9] investigated the incidence of doping in young semi-professional Swedish cyclists (n=8) through individual, semi-structured interviews. All the cyclists took products to improve performance, and all except for one cyclist reported that they would use illegal/banned products and methods if they turned professional.

2.7.1.1 Reasons for using ergogenic aids in cycling

A compelling attraction for athletes is the achievment of good results in performance with minimal effort [54]. Cyclists are always looking for ways to alter their bodies for maximal performance [67]. It is assumed that all professional cyclists train strenuously and therefore, any practice or substance providing a competitive edge may be encompassed as part of performance enhancement [52]. As discussed, cyclists will exploit training strategies, technological innovations and scientific, as well as medical support, to seek ways of improving performance and defeating their opponent [67,68]. Foregoing a potential advantage for maintaining the idealistic notions of sportsmanship, equity and fairness in competition may not always fall within the athlete's logic of success [69]. Devotion of time, long-term commitment and sacrifice in the professional cycling world often results in the cyclist trying to obtain for the best sponsorship, finance and, most importantly, individual glory [67,68,70]. On the other hand, however, one might also say that doping is demand driven. Aggression, speed, size, strength and winning are sometimes seen as the qualities society demands of sport [8].

Laraschi et al[6],using a questionnaire study, reported reasons to explain doping among cyclists (n=40). Fifty-seven percent of the study's participants said cyclists dope to gain advantages in physical performance, to achieve results within a short time (40%), to obtain good results during competition (38%) and because it was a common habit and practice amongst other cyclists (8%).

Personal attitude and the social environment can influence the use of both legal and illegal/banned ergogenic aids. Of particular concern, are the young cyclists who are striving to become professional. They are exposed to high pressures and often turn to the more experienced cyclists for advice. These older and more experienced cyclists are more likely to have used banned substances at some stage in their careers [6].

There is little evidence to support the use of most ergogenic aids based on the beneficial effects claimed in advertising [6,13]. The advantages of using ergogenic substances on sporting performance is highly controversial and athletes risk jeopardising their long-term and immediate health in using some of these ergogenic aids [6,13].

2.8 ERGOGENIC AIDS USED IN CYCLING: AN EVALUATION OF EVIDENCE

The categories of ergogenic aids receiving the most attention in the literature on cycling performance are the nutritional aids, pharmacological aids and the physiological aids [18]. The following section will evaluate the current evidence for the effectiveness of nutritional, pharmacological and physiological ergogenic aids on cycling performance.

Short-duration, high-intensity exercise improves the buffering capacity of muscles and thus increases the ability of a cyclist to sustain a higher power output or percentage of VO_{2max} over an increased period of time [27]. Both of these parameters, average power output and relative VO_{2max} are probably the most important predictors of cycling performance [34]. The studies assessed in this review used these two performance parameters, along with time-to-fatigue to evaluate the ergogenic effect of specific aids used in cyclists. An increase in power output will enhance short-duration high-intensity exercise performance, important for the time trial component of cycling competitions. An increase in VO_{2max} and time-to-fatigue are both largely related to enhancing endurance performance. The level of evidence (LOE) according to evidence-based medicine criteria will be evaluated in all clinical trials presented in this section of the review [71].

2.8.1 Nutritional aids

The nutritional requirements of endurance cyclists are often challenging to meet due to extensive training and competition programmes. The nutritional needs and practices of cyclists are aimed at providing the muscles with adequate substrate to improve race performance and maximise training adaptations [4,72]. The detrimental effects of fatigue during endurance events may be reduced by nutritional strategies and supplementation before, during and after an event [3,4,30,31,73].

With the world standard in sport continuing to advance to higher levels, the smallest advantage can have a tremendous impact on performance [30,42,52]. Carbohydrates, PRO, amino acids, creatine and electrolytes will be discussed under nutritional ergogenic aids. These ergogenic aids will be reviewed as appropriate considering their physiological basis for use, strategies for use in cycling, current evidence for the effects of their use on cycling performance and the health risks associated with their use.

2.8.1.1 Carbohydrates

2.8.1.1.1 Physiological basis for CHO use

There are a number of proposed mechanisms by which CHO improves performance [74]. Some studies propose that liver and muscle (endogenous) glycogen is conserved when CHO is consumed during exercise [31,74]. During prolonged cycling at a moderate intensity, the ingestion of CHO had little effect on plasma glucose concentration; however, plasma glucose concentration dropped significantly after two hours when CHO was not ingested, indicating that perhaps, CHO, in fact did have an effect on plasma glucose concentration [72,75]. However the authors proposed that it was the maintenance of euglycaemia or high blood oxidation rates late in exercise that improves performance [74,76].

Of late it has been hypothesised that CHO ingestion may have a central effect [72]. Carter et al[77] conducted a study on trained cyclists (n=9) using a CHO solution and a placebo solution as a mouth wash (participants spat out the solution). The exercise protocol consisted of a 60-minute time trial. An improvement in performance was still observed in the CHO rinse group compared to the placebo group. The authors proposed that there may be receptors in the mouth communicating with the brain, and that metabolism and high blood glucose concentration do not necessarily play the only role [77].

The time at which CHO is ingested has little effect on the rate of CHO oxidation [76]. High rates of exogenous CHO oxidation should be reached as soon as possible after the onset of exercise. Repetitive ingestion throughout exercise has shown to increase the rate of gastric emptying and thus the rate at which CHO can be absorbed in the intestines [76]. Oral CHO oxidation occurs at a rate of 1 $g.min^{-1}$. The optimal amount to be ingested is 60 $g.h^{-1}$ to 70 $g.h^{-1}$ during exercise lasting longer than 90 minutes [72,76,78].

2.8.1.1.2 Strategies for CHO use in cycling

Strategies for manipulating CHO intake were first investigated by Swedish researchers in the late 1960s [19,79]. They demonstrated that endurance performance was improved following a high CHO diet by delaying the onset of fatigue [19,79]. Carbo-loading and CHO diet manipulation became highly popular in the 1970s, and the commercial marketing of CHO products increased. The original carbo-loading strategy initiated with athletes depleting their muscle glycogen stores through exercise, followed by two to five days of a CHO free diet, and finally ending with a high CHO diet for at least three days [19]. Endurance athletes, especially cyclists, found weight maintenance on this regime to be difficult. Many studies have investigated the effects of CHO as an ergogenic aid, and it has been well accepted in the literature that CHO ingestion can improve endurance capacity, by delaying the onset of fatigue [4,42,74,76,78-86].

Carbohydrate and fat stores are considered the most important substrate fuels for exercise [4,42,74,76,78-86]. During low to moderate intensity exercise (25% to 65% VO_{2max}) fatty acid oxidation provides majority of the total energy requirements [72,74,87]. Fat sources in the body are relatively abundant, and are derived from plasma free fatty acids and intramuscular triglycerides [72]. During high-intensity exercise (>75% VO_{2max}) CHO metabolism predominates. Endogenous CHO sources include muscle glycogen, liver glycogen and plasma glucose from exogenous CHO intake [72,74,87].

During the early stages of exercise, muscle glycogen supplies the majority of CHO energy. As exercise continues, muscle glycogen stores become depleted and the body relies more upon blood glucose [78]. Muscle glycogen is considered a vital fuel source, and once reduced, the ability to perform at the required intensity is reduced and performance may diminish [88,89]. It is well-accepted that endurance performance is influenced by the amount of glycogen stored in skeletal muscles, with fatigue often coinciding with skeletal muscle glycogen depletion [87,89,90]. Research has investigated the influence of increasing muscle glycogen stores by examining the timing, frequency, amount and type of CHO supplementation [88]. The goal of CHO ingestion is two-fold. Firstly, it is to optimise muscle glycogen stores leading up to an event, and secondly, to ensure the availability of CHO in the body in the later stages of prolonged exercise (>90 minutes). During prolonged exercise, if CHO stores are depleted, the ability to maintain intense exercise limits performance [78].

The types of CHO can be split into two groups according to their oxidation rates. Fructose and galactose have lower oxidation rates, whereas sucrose and glucose polymers are considered to be as efficient as glucose, as they have similar oxidation rates [76]. Similarly, whether the CHO is in a liquid or solid form, the ergogenic potential is not affected [80]. Therefore solutions containing glucose, sucrose and glucose polymers (maltodextrins) may be consumed and are equally beneficial [86].

On the day of an event athletes should consume CHO three to six hours before the event [79]. Carbohydrate ingestion 30 minutes before an event has shown to decrease endurance performance [75]. It results in a faster decline in muscle glycogen and blood glucose concentration, thus decreasing the time to fatigue [75]. Literature documenting the intake of CHO by female cyclists is scarce.

Burke[4] examined the nutritional practices of male and female cyclists, and found that male cyclists have a CHO intake of 8 $g.kg^{-1}$.day to 11 $g.kg^{-1}$.day during intensive training. The recommended daily allowance (RDA) for CHO is 60% (7 $g.kg^{-1}$.day to 10 $g.kg^{-1}$.day) of total energy intake and for athletes training more than four to five hours per day, 10 $g.kg^{-1}$.day to 12 $g.kg^{-1}$.day is recommended [4,72]. It was also found that pre-race and post-race CHO ingestion was the preferred practice.

2.8.1.1.3 Current evidence for the effects of CHO on cycling performance

The ergogenic effect of CHO ingestion has generally been demonstrated to improve endurance performance by delaying the onset of fatigue [80]. Hawley et al[91] concluded that CHO loading during prolonged continuous exercise at a fixed submaximal work rate improves endurance performance by 20%. Coyle et al[75] investigated the effects of CHO ingestion during prolonged cycling at 74% VO_{2max}. Trained cyclists (n=10) exercised for 180 minutes, and were instructed to maintain the highest workload possible for the full two hours. Cyclists were given a glucose polymer 20 minutes after the start. Exercise time-to-fatigue significantly increased in the CHO group compared to the placebo group ($p < 0.001$). Ivy et al[92] also found that the ingestion of a glucose polymer in trained cyclists, cycling at 71% VO_{2max}, for two hours, delayed fatigue in the CHO group compared to the placebo group. These findings both demonstrate that CHO ingestion in trained cyclists, during prolonged cycling at 70% to 75% VO_{2max} can delay the development of fatigue.

However some studies have failed to show improvements in performance with CHO ingestion [16,80,93]. Burke et al[93] observed that neither performance in a 100 km time trial nor average power output improved with a high CHO diet compared to a moderate CHO diet in endurance trained cyclists and triathletes (n=7). Pritchett et al[16] also failed to demonstrate an ergogenic effect of CHO ingestion on subsequent endurance performance in regional level cyclists and triathletes (n=10). Discrepancies between studies may be a result of different experimental designs, the type and amount of CHO ingested, as well as the method used to evaluate performance [74,80,93].

Nutritional strategies involving CHO supplementation have also been investigated during recovery between exercise sessions, to enhance glycogen re-synthesis and thus subsequent performance [81,85,90,94]. Fallowfield et al[85] were the first to demonstrate that the ingestion of a CHO-electrolyte drink after exercise enhances recovery. Runners completed two exercise protocols consisting of a 90 minute run (or run until exhaustion) at 70% VO_{2max} separated by a recovery period. Participants that consumed a 6.9% CHO solution within the first two hours of recovery ran 22.2 minutes longer in the subsequent run, compared to the placebo group. Muscle glycogen re-synthesis and storage peaks within the first hour after exercise [72]. It is therefore recommended that ingestion of moderate to high glycaemic index CHO are ingested as soon as exercise is completed, at an amount of 1 $g.kg^{-1}.h^{-1}$ to 1.8 $g.kg^{-1}.h^{-1}$ for maximum benefit. When recovery periods are limited, ingestion should start immediately [72].

Recently the combination of a CHO and PRO supplement has been shown to improve performance and recovery over CHO supplementation alone and this will be reviewed in Section 2.8.1.2 (page 28) [81,89,90,94,95]. Research has also examined the effects of a high fat diet over a high CHO diet on endurance performance. This type of diet is suggested to be beneficial for exercise where athletes have to carry their own supplies, energy expenditure is high and/or recovery time is limited [74]. There is limited evidence supporting a high fat diet and health risks warrant caution in promoting such a diet. Research has shown though, that adaption to a high fat, low CHO diet is possible, while maintaining endurance capacity [74]. Lambert et al[96] compared a high fat diet to a high CHO diet on endurance performance in trained cyclists. At moderate intensity exercise (60% VO_{2max}) time to exhaustion was significantly longer after the high fat diet ($p < 0.01$), however there was no difference in performance between the two diets at high-intensity exercise (90% VO_{2max}).

One of the major adaptations to endurance training is the increase in fat oxidation during exercise [74]. As a result; research has delved into investigating the performance effects of a high fat diet in trained athletes with an increased capacity for fat oxidation. The evidence is currently equivocal and conclusive answers are absent. Table 2.1 provides a summary of relevant experimental studies that assessed the ergogenic effects of CHO and the combination of CHO and protein, CHO and electrolytes, and CHO and fat on cycling performance [16,75,77,81,82,88,93-98].

Table 2.1: Summary of experimental studies that assessed the ergogenic effects of carbohydrates only, and a combination of carbohydrates and protein/electrolytes/fat on cycling performance.

Article	Study design	Sample size (n)	Participants	Intervention	Exercise protocol	Results	Conclusion
Coyle, Hagberg, Hurley, Martin, Ehsani & Holloszy[75]	Randomised, double-blind, cross over design LOE: I	10 participants (9 males and 1 female)	Highly trained cyclists	-Glucose polymer solution vs. PLA solution -50% polycose solution after 20 min of exercise (140 ml) -Then 6% polycose solution at 60, 90 & 120 min of exercise (300 ml) -PLA group had same volume of flavoured solution	-The highest workload the participant could maintain for 2 h at an average of 74% VO_{2max} -Instructed to cycle until fatigue or until 180 min	-Endurance performance was improved in 7/10 participants -TTF increased from 126 min to 159 min with CHO ingestion ($p < 0.001$)	CHO feeding during prolonged exercise can postpone the development of fatigue and has an ergogenic effect on endurance cycling performance.
Ivy, Res, Sprague & Widzer[95]	Randomised, double-blind, counter balanced design LOE: I	9 participants (males)	Trained cyclists	-7.75% CHO supplement (200 ml) -7.75% CHO/1.94% PRO supplement (200 ml) -Sweetened PLA supplement (200 ml) (Supplements were given before the start of exercise and then every 20 min until 80% VO_{2max} was reached)	-On 3 separate occasions participants cycled at intensities that varied between 45% and 75% VO_{2max} and then at 85% VO_{2max} for 3 h or until fatigue	-CHO supplementation significantly increased TTF (CHO 19.7 min vs. PLA 12.7 min) -The addition of PRO enhanced the effect of the CHO supplement ($p < 0.05$) -Endurance performance was increased by an additional 36% with the addition of PRO	The addition of PRO to a CHO supplement enhanced endurance cycling performance above that which occurred with a CHO supplement only.
Burke, Hawley, Schabort, St Clair Gibson, Mujika & Noakes[93]	Randomised, placebo-controlled, cross over design (Blinding not mentioned) LOE: II	7 participants (males)	Endurance trained cyclists and triathletes	-Individualised meal plans based on BW given 72 h before the trial -CHO-loading trial ($9\ g.kg^{-1}$) vs. PLA controlled moderate-CHO diet ($6\ g.kg^{-1}$)	-2 x 100 km TT on separate occasions, interspersed with 4 x 4 km and 5 x 1 km sprints	-Time to complete the TTs or the average PO during the TTs did not differ between the trials	CHO-loading did not provide an ergogenic effect on endurance cycling performance.

KEY: PLA: placebo; min: minutes; h: hour; VO_{2max}: maximal aerobic capacity; TTF: time-to-fatigue; CHO: carbohydrate; PRO: protein; BW: body weight; TT: time trial; PO: power output.

Table 2.1 (continued): Summary of experimental studies that assessed the ergogenic effects of carbohydrates only; and a combination of carbohydrates and protein/electrolytes/fat on cycling performance.

Carter, Jeukendrupt & Jones[77]	Blinded, counter balanced design (randomisation not explained, the investigators were not blinded) LOE: II	9 participants (7 males and 2 females)	Endurance trained cyclists	-6.4% CHO rinse solution vs. PLA rinse solution (5 seconds rinse and spit)	-1-h TT	-CHO rinse trial significantly improved performance: CHO: 59.57 min vs. PLA: 61.37 min ($p = 0.011$) -There was also a significant increase in PO in the CHO trial compared to the PLA trial ($p = 0.003$)	A CHO mouth rinse has an ergogenic effect. The mechanism responsible for the improvement performance may involve an increase in central drive or motivation rather than a metabolic cause.
Temesi, Johnson, Raymond, Burdon & O'Connor[97]	A systematic review with meta-analysis, of single and double-blinded, randomised, placebo-controlled, cross over design studies LOE: II	50 studies were included that met the review criteria	Abled bodied male and female participants	-CHO ingestion (not exceeding 8% and between 30 g/h and 80 g/h during exercise) vs. PLA (the PLA was required to be closely matched to the CHO treatment for taste, sweetness, colour, and/or texture)	-Cycling protocols of ≥1 h evaluated via: 1)TT: measuring time to complete a predetermined distance or amount of work; 2)TT: measuring distance completed or work done in a predetermined time; 3)A submaximal exercise bout immediately followed by a TT; 4)TTF: measured at a predetermined exercise intensity, speed, or PO; or 5)A submaximal exercise bout immediately followed by TTF	1&2)A mean performance improvement 2.0% with CHO 3)A mean performance improvement of 7.5% with CHO 4)A mean performance improvement of 15.1% with CHO 5)A mean performance improvement of 54.2% with CHO	The ingestion of CHO during endurance exercise of at least 1 h improves performance.

KEY: PLA: placebo; min: minutes; TTF: time-to-fatigue; CHO: carbohydrate; h: hour; TT: time trial; PO: power output; HIE: high-intensity exercise.

Table 2.1 (continued): Summary of experimental studies that assessed the ergogenic effects of carbohydrates only; and a combination of carbohydrates protein/electrolytes/fat on cycling performance.

Pritchett, Bishop, Pritchett, Green & Katica[16]	Randomised, counter balanced, repeated measures, cross over design (Blinding not mentioned) LOE: II	10 participants (gender not mentioned)	Regional level cyclists and triathletes	-Participants were given the recovery drinks: CHO-PRO (CHOC milk) or CHO beverage immediately after the first exercise session, and again 2 h into the recovery period -The beverages were iso-caloric	-2 trials: the first exercise bout consisted of a 50 min HI intermittent cycling protocol -Participants then received either a CHO beverage or CHOC milk -Participants returned to the laboratory 15 h to 18 h later, and completed a ride to fatigue at 85% VO_{2max}	-There was no significant difference between trials in TTF	CHO or CHO-PRO (CHOC milk) ingestion provided no ergogenic effect on endurance performance. In addition, neither beverage enhanced recovery between successive work outs.
Ivy, Goforth, Damon, Mccauley, Parsons & Price[88]	Rank ordered (according to VO_{2max}), counter balanced design (Blinding not mentioned) LOE: II	7 participants (males)	Trained cyclists	-Participants either received a CHO-PRO supplement or a high CHO supplement or a low CHO supplement 10 min after exercise and again at 2 h post exercise	-3 trials: 2 h of cycling at 65% to 75% VO_{2max}, followed by 2 min sprints at maximum effort for 30 min	-After 4 h of recovery, muscle glycogen was significantly greater for the CHO-PRO trial ($p = 0.004$) and high CHO trial ($p = 0.013$)	Endurance performance was not assessed; however a CHO-PRO supplement was more effective in the restoration of muscle glycogen than a high CHO supplement.
Thomas, Morris & Stevenson[94]	Randomised, counter balanced trial (Blinding not mentioned) LOE: II	9 participants (males)	Trained cyclists	-3 recovery drinks: given immediately post glycogen-depletion trial and 2 h into recovery 1)CHO-PRO (CHOC milk) 2)CHO drink 3)Fluid drink	-3 trials: a glycogen-depleting trial, a 4 h recovery period, and a cycle to fatigue at 70% VO_{2max}	-Participants cycled 51% and 43% longer after ingesting CHO-PRO drink (CHOC milk) than after ingesting a CHO drink ($p = 0.01$) and a fluid drink ($p = 0.01$) respectively	A CHO-PRO supplement (CHOC milk) consumed during recovery from endurance exercise, may enhance subsequent cycling performance.

KEY: CHOC: chocolate; CHO: carbohydrate; PRO: protein; h: hour; min: minutes; HI: high-intensity; TTF: time-to-fatigue; VO_{2max}: maximum aerobic capacity.

Table2.1 (continued): Summary of experimental studies that assessed the ergogenic effects of carbohydrates only; and a combination of carbohydrates protein/electrolytes/fat on cycling performance.

Saunders, Kane & Todd[81]	Randomised, double-blind, counter balanced design LOE: I	15 participants (males)	Trained cyclists	-CHO only trial (7.3%) vs. CHO-PRO trial (7.3%; 1.8%) beverages consumed every 15 min during trial and 10 ml.kg^{-1} after exercise	-Ride 1: 75% VO_{2max} to fatigue, 12 h to 15 h later, -Ride 2: cycle to fatigue at 85% VO_{2max}	-Ride 1: participants rode 29% longer with the CHO-PRO beverage ($p < 0.05$) than with the CHO only beverage -Ride 2: participants rode 40% longer with CHO-PRO compared to CHO only beverage	A CHO beverage with the addition of PRO produces significant improvements in TTF, thus enhancing endurance cycling performance.
Davis, Lamb, Pate, Slentz, Burgess & Bartoli[82]	Double-blind, counter balanced design (Randomisation not mentioned) LOE: II	19 participants (males)	Well trained cyclists	-PLA drink vs. low CHO-electrolyte (2.5%) drink vs. moderate CHO-electrolyte (6.0%) drink (first drink 15 min into exercise, then every 20 min during exercise)	-Ride 1: 2 h cycling at 75% VO_{2max}, then 30 min rest -Ride 2: 30 min cycle at 75% VO_{2max}	-Ride 2 was performed faster with the moderate CHO-electrolyte drink compared to the PLA ($p = 0.02$)	A CHO-electrolyte drink can improve endurance cycling performance.
Angus, Hargreaves, Dancey & Febbraio[98]	Randomised, double-blind, cross over design LOE: I	8 participants (males)	Endurance trained cyclists and triathletes	-250 ml every 15 min of exercise of either PLA vs. CHO drink (6.0%) vs. CHO-MCT drink (6.0%; 4.2%)	-100 km TT	-When participants consumed either of the two CHO containing drinks (CHO or CHO-MCT), times to complete the TT were reduced ($p < 0.05$) by 7% and 5% respectively, compared with PLA (CHO: 166 min vs. CHO-MCT:169 min vs. PLA: 178 min)	CHO ingestion during exercise improves 100 km TT performance compared with PLA, but the addition of MCT to a CHO beverage does not provide any enhanced ergogenic effect.
Lambert, Speechly, Dennis & Noakes[96]	Randomised, cross over design (Blinding not mentioned) LOE: II	5 participants (males)	Endurance trained cyclists	-2 weeks high fat diet vs. 2 weeks high CHO diet	-30 s Wingate test, 30 min rest, followed by a cycle to fatigue at 90 % VO_{2max} (HIE) followed by a cycle at 60% VO_{2max} (MIE)	-No difference in HIE -TTF was longer in the subsequent MIE in the high fat diet vs. high CHO diet (79.7 min vs. 42.5 min; $p < 0.01$)	There is an ergogenic effect on endurance performance in MIE following a 2 week adaption to a high fat diet.

KEY: CHO: carbohydrate; PRO: protein; min: minutes; BW: body weight; VO_{2max}: maximum aerobic capacity; TTF: time-to-fatigue; PLA: placebo; h: hours; MCT: medium chain triglycerides; TT: time trial; s: seconds; HIE: high-intensity exercise; MIE: moderate-intensity exercise.

Carbohydrates can be considered an effective nutritional ergogenic aid for endurance cycling performance. Carbohydrate ingestion delays the onset of fatigue during prolonged cycling [75,92,95,97]. Beneficial effects have been shown when consuming CHO three to six hours before an event, and when ingesting 60 $g.h^{-1}$ to 70 $g.h^{-1}$ during exercise lasting longer than 90 minutes [72,76,78,79]. The ergogenic potential is not affected by the form in which CHO are ingested [80]. Both combinations of a CHO-electrolyte beverage and a CHO-protein beverage enhance muscle recovery post training and/or competition [72,81,88-90,95,99-102]. An improved recovery rate will allow the capacity for larger training volumes, which provide the stimulus for enhanced physical adaptations that can further improve cycling performance [31].

2.8.1.2 Protein and Amino acids

One of the most popular and heavily marketed supplements today is PRO [103,104]. Athletes supplement with PRO and amino acids with the hope to increase muscle mass and strength, and thus enhance performance [42,104-106].

There are 20 amino acids, 11 of which are synthesized in the body and nine of which have to be obtained through the diet (essential amino acids) [105]. Three essential amino acids; leucine, isoleucine and valine are known as branched chained amino acids (BCAA), due to their structural similarity [105]. These BCAA have been popular in recent research with regards to their ability to enhance performance, though their benefit remains controversial [105].

2.8.1.2.1 Physiological basis for PRO and amino acid use

Branched chained amino acid availability has been hypothesized to play a role in central fatigue [106]. During prolonged exercise, and specifically in endurance athletes, BCAA metabolism is activated. As exercise continues, there is a decline in plasma BCAA concentration and an increase in free fatty acid concentration. The increase in free fatty acids displaces tryptophan from albumin. The displaced and now free tryptophan readily crosses the blood brain barrier, and forms serotonin, which depresses the CNS and increases the perception of fatigue [95,104-106]. As a result of this proposed mechanism of action on the CNS, research supplementing with BCAAs to increase time to fatigue, and thus endurance performance was undertaken. Research results are equivocal and BCAA supplementation currently lacks substantial scientific proof as an ergogenic aid.

The RDA for PRO is 0.8 $g.kg^{-1}$.day for sedentary adults, with the requirements of athletes being greater at 1.2 $g.kg^{-1}$.day to 1.8 $g.kg^{-1}$.day for resistance and endurance sports alike [103-105]. The additional needs for PRO are easily obtainable in the diet and thus supplementation maybe considered unnecessary. Athletes often ingest higher amounts of PRO than that of the RDA, and supplementation allows for minimal change to their diet with increased protein intake, but without increased fat ingestion [42,103].

2.8.1.2.2 Current evidence for the effects of PRO on cycling performance

Recently the combination of a CHO and PRO supplement has been shown to improve performance and recovery over CHO supplementation alone [81,88-90,95,99-102]. Saunders et al[81] investigated the effects of a CHO-PRO beverage on cycling endurance. Cyclists (n=15) cycled to fatigue at 75% VO_{2max}, had a 12 hour to 15 hour recovery period and then cycled at 85% VO_{2max} until exhaustion.

Both beverages were matched for CHO concentration (7.3%), with one of the CHO beverages having the addition of PRO. The beverages however were not matched for calorie content. Time-to-fatigue in the CHO-PRO trial was significantly increased ($p < 0.05$) during the first test (29% longer), and during the second test (40% longer) compared to the CHO-only trial [81]. The increase from 29% to 40% also suggests that the addition of PRO may enhance muscle recovery. Whether the higher calorie content in the PRO drink or the PRO itself caused an increase in performance, was unclear and remains unclear in current literature. Ivy et al[95] simulated a competitive cycling event, which lasted 180 minutes of varying intensity (45% to 75% VO_{2max} and then 85% VO_{2max}), also found that cyclists ingesting a CHO-PRO beverage were able to sustain exercise at 85% VO_{2max} for 36% longer than when ingesting a CHO-only beverage. These two studies showed positive effects of the co-ingestion of CHO and PRO for enhancing endurance performance and recovery, over CHO ingestion alone. However the major flaw of these studies is that, the calorie content of the beverages were not matched. With regards to the type of PRO used to date all studies which have shown enhanced endurance performance in cyclists, have used whey PRO or casein hydrolysate [81,95,107].

The co-ingestion of CHO and PRO was also found to enhance recovery in many other studies [81,88,95,101,105]. Zawadski et al[108] demonstrated that the co-ingestion of CHO and PRO was more effective in the replenishment of muscle glycogen in the four hours immediately after exercise, than CHO alone. The authors hypothesised that an increase in muscle glycogen storage would be due to an increase in the plasma insulin response, however, this was not found to be the case. Other studies however, have proposed this to be the mechanism by which the addition of PRO acts, as insulin stimulates glucose uptake into the muscles and activates glucose synthase [95,100].

Thus it is thought that, if the effect of the insulin spike can be increased with the co-ingestion of CHO and PRO, compared to CHO alone, then recovery should be increased. A quicker recovery time will allow a quicker return to training at the required intensity or competition at full capacity [88]. On the other hand, there are studies that have found no effect of the co-ingestion of CHO and PRO on muscle glycogen synthase during early recovery [100].

The co-ingestion of CHO and PRO remains controversial as a high CHO intake post exercise has shown to enhance recovery effectively. It is suggested that co-ingestion only works if CHO intake is <1.2 $g.kg^{-1}.h^{-1}$ to achieve a maximal glycogen re-synthesis rate [72,100]. There are very few studies demonstrating an ergogenic effect of PRO and amino acid supplementation on endurance cycling performance [42,104-106]. Branched chained amino acids supplementation also currently lacks substantial scientific proof as an effective ergogenic aid. The additional needs of PRO for an athlete are easily obtainable in the diet, and thus supplementation is considered unnecessary.

2.8.1.3 Creatine

Creatine was first identified in 1835, however it was not until the 1990s that creatine supplementation to enhance performance became popular [11,109,110]. The popularity stemmed from a study carried out by Harris et al[111] which was the first study to investigate the effects of creatine supplementation. The authors demonstrated that the ingestion of small amounts of creatine supplement (less than 1 g) had insignificant effects on the body, whereas higher amounts (5 g) increased skeletal muscle creatine by 15%.

2.8.1.3.1 Physiological basis for creatine use

Creatine is an amino acid derivative, which is synthesized in the liver, pancreas and kidney [11,110,112-114]. The RDA is 2 g, half of which is provided by endogenous synthesis and the rest via diet [20,42,112-114]. Of the total creatine in the body, 95% is stored in skeletal muscle, two thirds of which is stored as phosphocreatine, and the remaining third as free creatine [11,20,42,112-114]. Phosphocreatine is primarily responsible for the re-synthesis of ATP from adenosine di-phosphate during anaerobic activity [11,20,42,112-114]. The amount of ATP re-synthesized is dependent on the availability of phosphocreatine in the muscle [110]. Short-duration, high-intensity exercise such as sprinting and weightlifting rely profoundly on the phosphocreatine-ATP energy system [110]. During exercise phosphocreatine is depleted relatively quickly, re-synthesis of ATP thus decreases which results in an inability to sustain high-intensity exercise and maximum effort over a prolonged period [113].

Creatine supplementation is thus proposed to be ergogenic as it has the potential to increase ATP production [11]. The proposed mechanism states that an increase in creatine will increase phosphocreatine stores in skeletal muscle. This will lead to an increased rate of ATP regeneration, increasing maximal energy production [20].

2.8.1.3.2 Strategies for creatine use

Generally, the ergogenic dosage that has been consistent through the literature follows a loading protocol. This consists of 20 g.day to 30 g.day for five to seven days, followed by a maintenance dose of 2 g.day to 3 g.day over a longer period [11,20,42,112-114]. There are many forms of creatine available, but most studies have used and have found beneficial effects with creatine monohydrate [11,20,42,112-114]. Recently, the addition of CHO and a combination of CHO and PRO ingestion has shown to augment muscle retention of creatine [113].

2.8.1.3.3 Current evidence for the effects of creatine on cycling performance

Creatine supplementation has been extensively studied as a nutritional ergogenic aid for athletes and controversy still surrounds its use [113]. Literature documents mixed results, which is thought to be due to athletes/participants having baseline values at creatine saturation levels, and are therefore "*non-responders*" [20]. The creatine level prior to supplementation is the most important factor governing the increase in skeletal muscle creatine post supplementation [2,11,20,42,52,110,113,115].

Ziegenfuss et al[116] conducted a double-blind placebo-controlled study, which assessed the effects of three days of creatine supplementation on cycling power output (n=20). The cycling protocol involved six ten second sprints at maximal effort pre-creatine/placebo supplementation and post-creatine/placebo supplementation. Creatine supplementation resulted in a significant ($p < 0.04$) increase in total work during the first sprint and increased peak power during sprints two to six.

The majority of the studies have concluded ergogenic effects of creatine in short-duration, high-intensity exercise lasting less than 30 seconds [11,20,42,110,112-114,116,117]. The one proposed mechanism of action is that creatine supplementation improves the rate of re-synthesis of phosphocreatine allowing a for faster recovery time. This translates into an increased capacity to do work during training, and therefore improved training adaptations and cycling performance [42,113]. There are however, a few recent studies that have contradicted the ergogenic effects of creatine supplementation on short-duration high-intensity cycling performance [118-120].

With regards to sports performance and creatine use, there is less evidence to support creatine supplementation on endurance performance, and in general activities lasting longer than three minutes [115]. Only a few papers since the year 2000 have addressed the ergogenic effects that creatine might have on submaximal endurance performance [115].

Rico-Sanz and Marco[121] in a randomized placebo-controlled study, assessed the effects of creatine supplementation on endurance cycling performance. The exercise protocol consisted of bouts of exercise at varying intensities. Participants were all highly trained cyclists (n=14). The creatine group increased time to fatigue from 29.9 minutes to 36.5 minutes, while there were no changes seen in the placebo group. From their results, the authors concluded that there was an ergogenic effect of creatine supplementation on endurance cycling performance. Table 2.2 provides a summary of relevant experimental studies, adapted from Bemben and Lamont[115] that assessed the ergogenic effects of creatine in both short term high intensity cycling and endurance cycling, from the year 2000 onwards [116-122].

2.8.1.3.4 Health concerns associated with creatine use

The side effects of creatine supplementation are mostly based on anecdotal data, with no studies proving the documented short term effects of dehydration, cramping, nausea, seizures and gastrointestinal discomfort [11,20,42,110,112-114]. The only well researched side effect is an increase in weight, which is said to be a result of the osmotic effect of creatine [11,20,42,110,112-114]. No studies to date have published results on the long term effect of creatine supplementation, and here warrants caution to its long term use [11,20,42,110,112-114].

Creatine can be considered an effective nutritional ergogenic aid for short duration, high intensity exercise such as weight-lifting. Creatine however is not banned by the IOC as it is readily available in food sources such as fish and meat [11,20,42,110,112-114]. Results on the effect of creatine supplementation on short duration high intensity cycling, such as time trials, are conflicting. More research specifically looking at the effect of creatine on cycling performance is needed. There are very few studies demonstrating an ergogenic effect of creatine supplementation on endurance cycling performance [121]. This could be anticipated when considering the proposed mechanism of action of creatine. Creatine can therefore not be advocated as an effective ergogenic aid for endurance cycling due to the lack of evidence. At present, short term supplementation is regarded as safe when the recommended regimes are followed, however the long term effects are unknown at this stage [11,20,42,110,112-114].

Table 2.2: Summary of experimental studies that assessed the ergogenic effects of creatine on cycling performance from 2000 onwards (adapted from Bemben and Lamont, 2005[115]).

Article	Study design	Sample size (n)	Participants	Intervention	Exercise protocol	Results	Conclusion
Ziegenfuss et al[116]	Double-blind, placebo-controlled, randomised-block design LOE: I	20 participants (10 males and 10 females)	Highly trained university athletes	-Creatine group (n=10): 0.35 g.kg^{-1} FFM for 3 days vs. PLA group (n=10): 0.35 g maltodextrin.kg^{-1} FFM for 3 days	-6 x 10 s sprints at maximal effort, with 60 s recovery between sprints (pre-trial and after 3 days of treatment)	-Creatine supplementation resulted in an increase in total work during the first sprint ($p < 0.04$), and an increase in peak power during sprints 2 to 6	There is an ergogenic effect of 3 days of creatine supplementation on short duration HI cycling.
Green, McLester, Smith & Mansfield[118]	Randomised, placebo-controlled design (blinding not mentioned) LOE: II	19 participants (males)	Physically active	-Creatine group (n=9) 20 g/day vs. PLA (n=10) 20 g sucrose & maltodextrin/day for 6 days	-3 x Wingate cycle tests	-No significant difference in mean PO -No change in peak power for both groups	No ergogenic effect of creatine supplementation on short duration HI cycling.
Wiroth, Bermon, Andreis, Dalloz, Hebuterne & Dolisi[117]	Randomised, double-blind placebo-controlled design LOE: I	42 participants (gender not mentioned)	-Group 1: 14 (older) sedentary -Group 2: 14 trained cyclists -Group 3: 14 (young) sedentary	-Creatine group (n=7 for each participant group 1-3) 15 g/day vs. PLA group (n=7 for each participant group 1-3) for 5 days	-5 x maximal 10 s sprints with 60 s recovery between each sprint	-Maximal PO was significantly increased in group 1 and group 3 (the sedentary groups)	This suggests that creatine has an ergogenic effect in short duration HI cycling. However, an effect was only seen in previously untrained older and younger populations, but not in previously trained individuals.
Jones, Carter, Pringle & Campbell[122]	Cross over design LOE: II	9 participants (males and females)	Young and active	-Creatine group (n=5) 20 g/day for 5 days followed by 5 g/day maintenance dose vs. Control (n=4)	-Submaximal cycling (no time frame given)	-There was no difference in performance between the groups	There was no ergogenic effect of creatine supplementation on submaximal cycling performance.

KEY: FFM: free fatty mass; PLA: placebo; s: seconds; PO: power output; HI: high-intensity.

Table 2.2 (continued): Summary of experimental studies that assessed the ergogenic effects of creatine on cycling performance from 2000 onwards (adapted from Bemben and Lamont, 2005[115]).

Rico-Sanz & Marco[121]	Randomised, placebo-controlled design (Blinding not mentioned) LOE:II	14 participants (males)	Highly trained cyclists	-Creatine group (n=7) 20 g/day vs. PLA group (n=7) for 5 days	-Cycling at intensities equal to 30% and 90% of peak power until fatigue -Participants cycled for a total of 5 x 3 min stages (alternating 30% and 90% of maximal PO)	-Creatine group increased TTF from 29.9 min to 36.5 min, while there were no changes observed in the PLA group	There is an ergogenic effect of creatine supplementation on endurance cycling performance.
Preen, Dawson, Goodman, Lawrence, Beilby & Ching[119]	Randomised, double-blind, crossover design LOE: I	8 participants (male)	Active and young	-Creatine group (n=4) 2 x 15 g vs. PLA group (n=4) on day 1 of testing -Same protocol done 14 days later	-80 min sprint cycling task consisting of 10 sets of multiple 6 s sprints -recovery varied from 24 s to 84 s	-There was no significant changes in cycling performance between the two groups	There is no ergogenic effect of creatine supplementation on short duration HI cycling.
Finn et al[120]	Randomised, placebo-controlled design LOE:II	16 participants (gender not mentioned)	Active triathletes	-Creatine group (n=8) 20 g/day vs. PLA grp (n=8) for 20 days	-4 x 20 s 'all-out' sprints with a 20 s recovery period	-There was no significant difference in performance between the two groups	There is no ergogenic effect of creatine supplementation on intermittent cycling performance.

KEY: PLA: placebo; min: minutes; PO: power output; TTF: time–to-fatigue; h: hour; s: seconds.

2.8.1.4 Electrolytes

Electrolytes are consumed by athletes and are marketed to athletes before, during and after exercises for a number of reasons [123]. Recommendations put forward by the American College of Sports Medicine (ACSM) and IOC Consensus Document on fluid intake during exercise, advocates drinking sufficient amounts of fluid to replace the fluid lost during exercise through sweat ,to maintain euhydration (normal total body water) [123,124]. This guideline proposes that deficits in total body water (hypo-hydration) have detrimental effects on aerobic performance due to increased cardiovascular and thermal strain [123,125]. The guideline also promotes sodium ingestion during exercise to replace the sodium lost through sweat during exercise [123,124].

The ASCM and IOC guidelines are based on early studies, which found that when electrolytes were ingested during and/or after exercise, plasma volumes were well-maintained [125]. This contributed to the addition of sodium in drinks and the marketing of sports drinks containing electrolytes to improve performance and aid recovery [125]. Research investigating the mechanism of action, as a result of the addition of electrolytes to sports drinks (mainly sodium, potassium and magnesium) has not been identified. It is also unable to determine if one drink is superior to another based on the different kinds and amounts of electrolytes in the drinks [125,126]. There is no documented evidence for enhanced performance or recovery when potassium and magnesium are added to sports beverages, and the results for the addition of sodium to sports beverages are conflicting [124,125].

These guidelines have recently caused much debate within the literature. Noakes[124] advocates that fluid consumption both during and post exercise should be "*ad libitum*", to thirst. He highlights the fact that the ACSM guidelines are not based on controlled, prospective clinical trials, and that all variables of exercise; intensity; duration; environmental conditions and the nature of the exercise have to be considered. Weight loss for example (due to water loss and slight dehydration) during cycling has an ergogenic effect as it improves cycling efficiency when climbing mountainous ascents [124]. The promotion of fluid consumption "*ad libitum*" further reduces the risk of athletes over-drinking and inducing hyponatraemic encephalopathy [124]. It was concluded at the 2005 International Consensus Conference on Exercise-Associated Hyponatraemia, that with the increasing consumption of salt (sodium) in the diet, above the RDA, that only during prolonged events (226 km Ironman), in extreme environmental conditions (heat and humidity), may a sodium deficit, as a result of sweating,contribute to decreased performance and potential exertional hyponatraemia [124].

The literature indicates somewhat conflicting results regarding this matter, with two schools of thought on fluid replacement and the benefits on aerobic performance. The evidence for the consumption of electrolytes to enhance performance and improve recovery is lacking, and there is no evidence supporting the use of electrolytes for the specific purpose of enhancing cycling performance. It may be further inferred that the addition of electrolytes is unnecessary in athletes who are consuming a well-balanced diet [126].

2.8.2 Pharmacological aids

Caffeine, vitamin supplementation, NSAIDs, analgesics, cortisone and HGH will be discussed under pharmacological ergogenic aids. These ergogenic aids will be reviewed considering their physiological basis for use, strategies for use in cycling, current evidence for the effects of their use on cycling performance and the health risks associated with their use.

2.8.2.1 Caffeine

Caffeine is a methyl xanthine that occurs naturally in coffee beans, tea leaves, cocoa, and plant species [127]. Food sources containing caffeine are relatively accessible, inexpensive and socially accepted, thus it is thought to be the most commonly used "*drug*" worldwide [128,129]. Sources include coffee, tea, energy drinks, soft drinks and chocolate [127,128]. In 1895, synthetic production of caffeine began [128]. Nowadays a variety of over-the-counter medications and prescription drugs also contain caffeine, for example, NSAIDs, analgesics, diuretics and simple cold and flu remedies [128]. Caffeine is classified as a non-essential nutrient but when large dosages are used, it may have pharmacological effects [39,128]. There is limited literature on the use of caffeine in sports as obtaining documented statistics on the frequency of use is difficult [130].

2.8.2.1.1 Physiological basis for caffeine use

There is conflicting evidence regarding the exact mechanism of action of caffeine [79,103]. The release of adrenalin (epinephrine), which increases mobilization of free fatty acids from adipose tissue, increasing fat oxidation, thus sparing muscle glycogen and extending exercise time, is one proposed mechanism. Costill et al[131] demonstrated that after the ingestion of caffeine cyclists were able to cycle for 20% longer than the control group, when exercising to exhaustion at 80% VO_{2max}.

When the authors tested the participants after the exercise protocol, a significant increase in lipid metabolism was found. However, many studies have not supported this proposed mechanism of increased fatty acids and therefore this notion is not widely accepted.

Caffeine is an ATP antagonist; thus it acts on most, if not all tissues, including the CNS. Another proposed mechanism of action is that the arousal of the CNS causes increased mental alertness and decreased perception of fatigue [20,39,42,79,127,128,130,132,133]. Recent literature has supported the proposed ATP mechanism through stimulation of the CNS. For example, Doherty et al[134] investigated the effects of caffeine in a three-minute preload test in male cyclists (n=11). The cyclists were given 5 $mg.kg^{-1}$ one hour before exercise, which consisted of two minutes of cycling at maximum power output at a constant rate, followed by one minute of "*all-out*" effort. All cyclists post preload had a decreased rate of perceived exertion at 30 seconds, 60 seconds and 120 seconds respectively. There was also an increase in mean power output during the last minute of the test. The authors suggested that caffeine can alter the perception of effort and thus extend and improve performance.

The third proposed mechanism of action is that caffeine causes alterations in the release and uptake of calcium from the sarcoplasmic reticulum, thus acting directly on skeletal muscle, increasing its contractility [20,39,42,79,127,128,130,132,133]. This mechanism is vaguely described in the literature and thus the exact action of caffeine in the body remains elusive.

2.8.2.1.2 Strategies for caffeine use

Popular methods used in studies to administer caffeine include caffeine capsules or caffeine dissolved in solution [133]. Other methods of administration include suppositories, intramuscular injections and venous infusions [130]. Ergogenic studies have used dosages between 2 $mg.kg^{-1}$ and 9 $mg.kg^{-1}$ [79]. A double-blind cross-over study by Kovacs et al[135] investigated the effects of three different dosages of caffeine. They used male, trained cyclists and triathletes (n=15) in a one-hour cycling time trial. The dosages of caffeine used were 2.1 $mg.kg^{-1}$, 3.2 $mg.kg^{-1}$ and 4.5 $mg.kg^{-1}$ respectively. Even with the lowest dose of caffeine, an increase in performance was observed, with the highest dose showing no more benefit compared to the middle dose [135]. A dose of 3 $mg.kg^{-1}$ has proved to be effective in increasing endurance, whilst a dose between 3 $mg.kg^{-1}$ and 6 $mg.kg^{-1}$ is recommended to be optimal [130,133].

Dosages exceeding 9 mg.kg^{-1} risk approaching the IOC disqualification limit, which is determined by a urine concentration of 12 ug.ml [42,79,130,136]. The literature shows that the beneficial effects of caffeine on performance can be met at doses that are well below the IOC urinary threshold. An athlete's habitual use of caffeine may alter the dose of caffeine needed for an ergogenic effect to be observed [133]. Although the ergogenic effects continue to be demonstrated, caffeine was removed from the WADA prohibited list in 2004. However, it remains in the Monitoring Programme to closely observe its potential misuse in sport [133].

Readily available sources of caffeine include coffee, tea and soft drinks; however, these are weaker sources compared to concentrated caffeine (i.e. in the capsule form) [130]. Consuming coffee to obtain an ergogenic effect is not the optimal method [42]. To exceed the IOC threshold an athlete would have to drink six to eight cups of very strong coffee an hour before exercise [42]. Caffeine is suggested to be consumed one hour before commencing exercise; however, timing of ingestion has shown not to be an important factor [133]. Ganio et al[133] conducted an extensive systematic review and subsequently advised athletes to abstain from habitual caffeine ingestion up to seven days before a competition, to maximise the ergogenic effect.

2.8.2.1.3 Current evidence for the effects of caffeine on cycling performance

A study investigating the effects of caffeine ingestion during short-duration exercise (15 seconds cycling) failed to show an improvement in maximum power output, work and fatigue indices [108]. This finding was later supported by Greer et al[137]. The authors also failed to demonstrate an improvement in short-duration cycling performance with caffeine ingestion [137]. However, recent studies have found improved performance after caffeine ingestion in short-duration high-intensity exercise [30,61]. Wiles et al[138] examined the effects of caffeine ingestion in trained cyclists (n=8) in a 1 km time trial. The participants were given 5 mg.kg^{-1} of caffeine one hour before the time trial. Results showed that peak power output improved by 75.5 W and performance time by 2.3 seconds. These gains may significantly influence cycling performance.

Caffeine has also shown to be effective in enhancing endurance in aerobic activities lasting 30 minutes and longer [131,132,134-136,139]. Ivy et al[92] showed a 7.3% greater total power output in a two-hour cycle test after the ingestion of caffeine. Although the literature shows the ergogenic effect of caffeine ingestion on endurance exercise lasting 30 minutes and longer, there are very few studies that investigate the effect of caffeine ingestion on ultra-endurance cycling (lasting more than six hours or over 100 km). More research specific to ultra-endurance performance effects is necessary.

The effects of caffeine on performance have been well-established in the literature [138]. However, the results are variable in terms of the degree of improvements [133]. The variability observed may be a result of different exercise procedures, the training statuses of the participants, as well as the use of different dosages of caffeine [138].

2.8.2.1.4 Health concerns associated with caffeine use

Compared to the many other ergogenic "*drugs*" available, the side effects of caffeine are considered minimal [103,127]. Documented side effects may include irritability, anxiety, restlessness, headaches and gastrointestinal disturbances [79,103]. The CNS side effects may result in dependency and withdrawal [79,103]. The diuretic side effect of caffeine, which may be seen as a problem in endurance events, is eliminated by exercise [20].

Ergogenic effects of caffeine may be beneficial for increasing endurance in training and in competition, as well as improving power output and performance in short-duration high-intensity exercise, for example, in a time trial [130]. There is good evidence to support the ergogenic effects of caffeine with the recommended dosages. Table 2.3 provides a summary of relevant experimental studies that assessed the ergogenic effects of caffeine ingestion, in both short-term high-intensity cycling and endurance cycling [92,131,132,134-141]. It is important to note that the majority of these studies have been carried out in controlled laboratory environments and not during actual competitions or training sessions.

In summary, caffeine is an effective ergogenic aid for increasing endurance performance, as well as improving power output and performance in short-duration high-intensity cycling [98,136-138,140,141,142,146]. Concentrated caffeine capsules and caffeine dissolved in solution are the most popular methods of ingestion and means in which to obtain an ergogenic effect [139]. The recommended dose to produce an ergogenic effect, which will still be below the threshold of the WADA Monitoring Programme, is 3 $mg.kg^{-1}$ to 6 $mg.kg^{-1}$ [130,133].

Table 2.3: Summary of experimental studies that assessed the ergogenic effects of caffeine on cycling performance.

Article	Study design	Sample size (n)	Participants	Intervention	Exercise protocol	Results	Conclusion
Greer, Mclean & Graham[137]	Randomised, double-blind, cross over design LOE: I	9 participants (males)	Recreationally active	-6 mg.kg^{-1} caffeine tablets vs. PLA tablets, 1 h before exercise	-4 x 30 s Wingate sprints, with 4 min rest between each sprint	-No effect on peak PO, average power or rate of power loss -Total PO was the same for both tests	No ergogenic effect of caffeine observed on repeated bouts of short duration HI cycling.
Wiles , Coleman, Tegerdine & Swaine[138]	Randomised, double-blind, cross over design LOE: I	8 participants (males)	Trained cyclists	-5 mg.kg^{-1} caffeine dissolved in a 250 ml lemon solution vs. 250 ml PLA lemon solution vs. C (nothing), 1 h before exercise	-1 km TT	-There was an improvement in cycling performance with caffeine ingestion compared to PLA and C (caffeine vs. PLA vs. C):71.1; 73.4; 73.3 min (p = 0.002) -Peak PO (p = 0.027) and average power (p = 0.007) also increased with caffeine compared to PLA and C	There is an ergogenic effect of caffeine on performance time in short duration HI exercise.
Ivy, Costill, Fink & Lower[92]	Randomised, double-blind, cross over design LOE: I	9 participants (7 males and 2 females)	Trained cyclists	-250 mg of caffeine 1 h before exercise, followed by the ingestion of an additional 250 mg fed at 15 min intervals over the first 90 min of the exercise vs. PLA	-2-h isokinetic cycling at 80% VO_{2max}	-PO increased by 7.3% with caffeine ingestion compared to PLA -The caffeine group cycled an average of 90.2 min compared to 75.5 min in the PLA group	There is an ergogenic effect of caffeine on endurance cycling performance and PO.
Cox et al[136]	Blinded, placebo-controlled, cross over design LOE:II	12 participants (males)	Highly trained cyclists and triathletes	-6 mg.kg^{-1} caffeine 1 h before (Pre-caf) -6 x 1 mg.kg^{-1} caffeine every 20 min (Dur-caf); -10 ml.kg^{-1} Coca-Cola in the last 50 min (~1 to 1.5 mg.kg^{-1} caffeine vs PLA	-2-h of steady state cycling at 70% VO_{2max} followed by a 30 min TT (CHO fed TT)	-Improvements in TT performance compared to PLA were as follows: Pre-caf: 3.4% (p = 0.04); Dur-caf: 3.1% and Coca-Cola: 3.1%	There is an ergogenic effect of caffeine on TT performance at the end of a 2 h endurance cycle.

KEY: PLA: placebo; s: seconds; min: minutes; h: hour; PO: power output; C: control; TT: time trial; VO_2max: maximum aerobic capacity.

Table 2.3 (continued): Summary of experimental studies that assessed the ergogenic effects of caffeine on cycling performance.

Jenkins, Trilk, Singhal, O'Connor & Cureton[140]	Blinded, placebo-controlled, cross over design LOE:II	13 participants (males)	Trained cyclists	-1 mg.kg^{-1}, 2 mg.kg^{-1}, or 3 mg.kg^{-1}, 1 h before exercise vs. PLA	-15 min cycle at 80% VO_{2max}, then 4 min of active recovery, followed by a 15 min TT	-Compared with PLA, caffeine doses of 2 mg.kg^{-1} and 3 mg.kg^{-1} increased performance by 4% (p = 0 .02) and 3% respectively	There is an ergogenic effect of caffeine on TT performance. (Although the effects were ergogenic they varied considerably in magnitude among individual cyclists.)
Kovacs, Stegen & Brouns[135]	Randomised, double-blind, placebo-controlled, cross over design LOE: I	15 participants (males)	Trained cyclists	-2.1 mg.kg^{-1}, 3.2 mg.kg^{1} and 4.5 mg.kg^{-1} doses vs. PLA; 75 min pre-exercise and at 20 and 40 min during TT	-Cycling TT of about ~1-h; CHO-fed during cycling	-Compared with PLA and the lowest dose of caffeine (2.1 mg.kg^{-1}), doses of 3.2 mg.kg^{-1} and 4.5 mg.kg^{-1} increased TT performance and work output (p < 0.001)	There is an ergogenic effect of caffeine, in relatively low doses, when added to a CHO–electrolyte drink in a 1-h TT.
Doherty, Smith, Hughes & Davison[134]	Randomised double-blind, placebo-controlled cross over design LOE: I	11 participants (males)	Trained cyclists	-5 mg.kg^{-1} caffeine diluted in 200 ml of artificially sweetened water vs. PLA 200 ml of artificially sweetened water, 1 h before exercise	-2 min cycling at maximal PO followed by a final 1 min 'all-out' effort, during which as much distance as possible was to be covered	-RPE (6 to 20 Borg scale) were lower in the caffeine trial compared to PLA (p < 0.05) -The average PO during the 'all-out' effort was increased following caffeine ingestion compared with PLA (p = 0.05)	There is an ergogenic effect of caffeine, in moderate doses, on performance time in short duration HI exercise.
Beck, Housh, Schmidt, Johnson, Housh, Coburn & Malek[141]	Randomised, double-blind, placebo-controlled design LOE: I	37 participants (males)	Resistance trained	-201 mg of caffeine tablet (n=17) vs. PLA tablet (n=20), 1 h before exercise	-2 x Wingate anaerobic tests	-The caffeine tablet had no effect on peak PO or average PO	No ergogenic effect of caffeine observed in short duration HI exercise.

KEY: h: hour; VO_2max: maximal aerobic capacity; min: minutes; TT: time trial; PLA: placebo; CHO: carbohydrate; PO: power output; RPE: rating of perceived exertion.

Table 2.3 (continued): Summary of experimental studies that assessed the ergogenic effects of caffeine on cycling performance.

Bell & Mc Lellan[132]	Randomised, double-blind, cross over design LOE: I	21 participants (15 males and 6 females) (13 caffeine users and 8 non-users)	Regularly active	-5 $mg.kg^{-1}$of caffeine vs. PLA (once per week at either 1, 3, or 6 h after ingestion)	-6 randomised exercise rides to exhaustion at 80% VO_{2max}	-Caffeine significantly ($p < 0.05$) improved TTF from 24.0 min during the PLA trials to 28.8 min in both users and non-users -This improvement was greater for the non-users -The effect of caffeine in the non-users was still evident 6 h after ingestion	There is an ergogenic effect of caffeine on endurance exercise performance. The duration and magnitude of the ergogenic effect of caffeine is greater in non-users compared with users.
Costill, Dalsky & Fink[131]	Randomised, double-blind, cross over design LOE: I	9 participants (7 males and 2 females)	Competitive cyclists	-330 mg of coffee (caffeine) vs. decaf coffee (PLA) 1 h before exercise	-Cycling at 80% VO_{2max} until exhaustion	-Caffeine improved TTF: 75.5 min during the PLA trial to 90.2 min in the caffeine trial	There is an ergogenic effect of caffeine on endurance exercise performance.
Ivy et al[139]	Randomised, double-blind, cross over design LOE: I	12 participants (6 males and 6 females)	Trained cyclists	-500 ml Red Bull (160 mg caffeine) vs. 500 ml flavoured PLA, 40 min before exercise	-Simulated TT ~1 h cycling at 70% VO_{2max}	-There was a significant increase in performance ($p < 0.01$) with caffeine compared to PLA: 61.5 min compared to 64.6 min	There is an ergogenic effect of caffeine on endurance exercise performance.

KEY: PLA: placebo; h: hour; VO_2 max: maximal aerobic capacity; TTF: time-to-fatigue; TT: time trial.

2.8.2.2 Vitamin supplementation

Vitamins are classified as either water-soluble (Vitamins B and C) or fat-soluble (Vitamins A, D, E and K) [11]. Water-soluble vitamins are metabolised and excess is excreted in the urine, whereas fat-soluble vitamins are stored in the liver and metabolised relatively slower, therefore carrying the risk of toxicity if large amounts are consumed [11]. Athletes often supplement with vitamins with the assumption that they can enhance performance [4,11,19,20,64]. Huang et al[64] found that the prevalence of vitamin supplementation was 65% among elite athletes at the 2000 Sydney Olympics. Cyclists demonstrated the highest use of mineral (73%) and nutritional supplementation (100%).

Popular vitamins include multi-vitamins (consisting mostly of B, A and D), Vitamin C, Vitamin A and Vitamin E [11,19,20,64]. Vitamin B is proposed to enhance aerobic power by providing enhanced energy [20]. Vitamin C is an anti-oxidant, which has a number of proposed benefits some of which are based on the symptoms of deficiency; decreased immunity, fatigue and weakness [11]. Therefore the assumed benefits of Vitamin C include enhanced immunity and enhanced aerobic power and thus endurance performance [11]. Vitamin E is commonly used as it is alleged to decrease the symptoms of DOMS [20,42]. Currently there is little literature to support supplementation with vitamins, minerals and anti-oxidants for athletes following a normal healthy diet [55]. Athletes who are on a stringent calorie-restricted diet or who are vegan may benefit from vitamin supplementation [20,42,64]. The ACSM, the American Dietetic Association, and the Canadian Dietetic Association, have all declared that athletes do not require vitamin/mineral supplementation if energy intake is sufficient to maintain body weight during training or competition [55].

There is a scarcity of scientific evidence showing benefit of vitamin supplementation on exercise performance in endurance athletes [11,20,42,64]. Consequently, the intense marketing and promotion of vitamin and mineral supplementation surpasses the empirical evidence supporting their use as ergogenic aids in cycling [11,20].

2.8.2.3 Non-steroidal anti-inflammatories, analgesics and cortisone

2.8.2.3.1 Physiological basis for NSAIDs, analgesics and cortisone use

The pain relief and anti-inflammatory properties of analgesics and NSAIDs may be seen as an appealing modality for cyclists to treat training-related soreness and enhance recovery [15,41]. Non-steroidal anti-inflammatories work by inhibiting the cyclo-oxygenase (COX) enzymes which are responsible for synthesising certain modulators of inflammation, specifically prostaglandins [15]. There are two classes of NSAIDs, which differ according to their inhibition of COX enzymes, either COX 1 or COX 2.The COX 2 enzyme has the same pain relieving effects as COX 1, but has a greater anti-inflammatory effect [15].

Analgesics unlike NSAIDs can only reduce pain and not inflammation. The mechanism of action of analgesics such as paracetamol is uncertain, however they have demonstrated to act centrally (at the CNS) rather than peripherally (at nerve endings) [142]. The stronger opioid analgesics (e.g. codeine and morphine) are used for both acute and chronic pain. They act on the cerebral opioid receptor system, which is involved in setting an individual's pain threshold as well as controlling pain processing [142].

One of the greatest advances in medicine has been the use of cortisone to suppress inflammation [143]. Cortisone inhibits the early phase inflammatory reactions as well as the late phase inflammatory reactions, and is often used in sport to treat overuse injuries [143]. Since the 1960s, athletes have used gluco-corticosteroids (cortisone) to improve performance [144]. It is used to ease exercise related pain and reduce sensations of tiredness and discomfort [65]. Gluco-corticosteroids work by increasing gluconeogenesis and the mobilisation of amino acids and fatty acids, thus increasing energy production and potentially improving recovery [144]. All forms of cortisone are prohibited in sport, and a TUE certificate is required if cortisone is needed to treat a diagnosed medical condition [144].

2.8.2.3.2 Current evidence for the effects of NSAIDs, analgesics and cortisone use on cycling performance

There is little available literature on the ergogenic effects of NSAIDs and analgesics on sports performance in general, and cycling performance specifically. Of the reviewed literature, researchers have mainly investigated the effects of NSAIDs on recovery, specifically DOMS after a bout of eccentric exercise [15]. In cycling, except in some instances of downhill mountain biking, there is very little eccentric muscle damage and therefore DOMS is not really an issue.

Nonetheless, results showed no effect of NSAIDs on muscle soreness or restoration of muscular function [15]. In fact, Ibuprofen, an over–the-counter anti-inflammatory, blunted the protein synthesis response in untrained men after a bout of eccentric exercise [15]. Long-term repeated use of NSAIDs may therefore negatively affect training adaptions [15,144].

O'Grady et al[145] examined the effects of diclofenac (NSAID) on objective indices of EIMD in a randomized double-blind, placebo-controlled trial (n=54). Diclofenac or a placebo was administered twice a day for 27 days. On day 15, participants took part in an exercise protocol of stair climbing to induce muscle damage. Muscle samples post-exercise revealed that the diclofenac group had less muscle tissue damage than the placebo group ($p < 0.002$). The authors concluded that NSAIDs can significantly reduce objective indices of EIMD. The practicality of what the authors are suggesting: pre-administration of NSAIDs to help decrease EIMD, is impossible. The cycling competitive season is extended over months, and athletes cannot continue the use of NSAIDs over an entire season.

Although there is a lack of scientific evidence demonstrating the effectiveness of NSAIDs as an ergogenic aid, anecdotal evidence suggests that the prevalence of use is high amongst athletes. At the XV Pan-American Games in 2007, 63% of all athletes were reportedly using medication [146]. The most frequently used type of medication was NSAIDs [146]. In-competition use was reported to be higher than out-of-competition use [146]. The authors proposed that athletes use NSAIDs as ergogenic aids to suppress the rate of perceived exertion, therefore prolonging endurance performance [146]. However, there is a scarcity of sound clinical evidence demonstrating this performance enhancing effect of NSAIDs.

Barlas et al[147] investigated the efficacy of commonly available analgesics on DOMS. Participants (n=60) were randomly allocated to one of five experimental groups: control, placebo, aspirin (900 mg), codeine (60 mg), and paracetamol (1000 mg). DOMS was induced in the elbow flexors through a bout of eccentric exercises. There was no evidence of effectiveness in any of the groups, and the authors concluded no beneficial effects of analgesic medication in the management of DOMS. Smith et al [148] also examined the effect of asprin and acetaminophen (paracetamol) on DOMS after a bout of eccentric exercise. There were no significant differences in perception of soreness between the groups (asprin, acetaminophen and placebo), and results indicated no effect of these analgesics on reducing the DOMS response.

2.8.2.3.3 Health risks associated with the use of NSAIDs, analgesics and cortisone

The use of NSAIDs carries the risk of renal, gastrointestinal and cardiovascular health risks, and are recommended to be used with caution [15]. The continued use may also present clinical implications for injury susceptibility in the future [149]. Doctors and pharmacists need to be aware of how medicines interact with exercise, performance, environment and other medicines to best manage athletes under their care [149].

Analgesics generally have fewer side effects than NSAIDs, but when analgesics are taken excessively or with alcohol, they can cause liver and kidney damage [150]. Analgesics are present in many over-the-counter cold and flu medicines, and therefore users may not realise they are taking too much and risk overdose. The side effects of opioid analgesics include drowsiness, dizziness, respiratory depression, constipation, and urinary retention [150]. The continued use of opioid analgesics (e.g. codeine) can cause tolerance to the drugs' analgesic effects and may lead to addiction [150]. The long-term use of cortisone has detrimental side effects including osteoporosis, tendon ruptures, joint and cartilage degeneration, delayed healing, increased scar formation and delayed muscle regeneration [144].

There is no evidence supporting the use of NSAIDs and analgesics as ergogenic aids in endurance cycling performance. Most studies have investigated the effects of these medications on DOMS and EIMD after bouts of eccentric exercise. The literature is conflicting and no clear inferences can be made from these clinical trials. The evidence for cortisone specifically enhancing endurance performance is limited. There is however strong evidence for its ability to supress inflammation.

2.8.2.4 Growth hormone

It is believed that HGH has been used extensively by athletes since the 1980s for its anabolic and lipolytic properties [11,18,127,151-154]. With anabolic steroids now more easily detected in doping controls, and currently no reliable tests available for HGH, its popularity persists. However, there is no scientific literature supporting or proving an ergogenic effect of HGH in healthy individuals [11,18,103,112,127,151-154].

2.8.2.4.1 Physiological basis for HGH use

Human growth hormone is a polypeptide hormone that is produced by the anterior pituitary gland [104]. It was not until the 1950s, when researchers realised that HGH stimulated skeletal, soft tissue, bone and cartilage growth [127]. Shortly thereafter it was used to treat children and adults with growth hormone deficiency and Turners Syndrome. The effects of therapeutic administration were dramatically seen, with increases in muscle mass, decreases in fat mass and increases in cardiac output and performance [153]. It thus developed a reputation for increasing muscular strength, size and performance. Its abuse became popular particularly amongst cyclists, swimmers and bodybuilders [127,154]. At the 1998 Tour de France officials found large amounts of HGH and other doping substances being carried by a cycling team and their physiotherapist, signifying misuse within the team and among cyclists [127,154]. The Festina affair, which was highly publicised, refers to the events that followed this finding. They included several doping scandals, investigations and confessions by professional cyclists that occurred following the 1998 Tour de France [125,154].

Human growth hormone stimulates most tissues, including the synthesis of insulin-like growth factor one (IGF-1) in the liver [11,18,103,112,127,151-154]. The physiological actions of HGH and IGF-1 have an anabolic effect on the body. These hormones regulate and increase protein synthesis, whilst insulin inhibits protein catabolism, thus increasing muscle mass. The combination also increase fat oxidation resulting in a subsequent decrease in body fat mass [11,18,103,112,127,151-154].

2.8.2.4.2 Strategies of use

Human growth hormone is readily available although it is legally only a prescription drug. It is administered either subcutaneously or intramuscularly, generally with a therapeutic dose of 1.5 mg.day given three times a week [127]. The use of black market HGH is a real concern as it is derived from cadaveric specimens and runs the risk of Creutzfeldt-Jakob disease in the recipient [11,18,103,112,127,151-154]. Anecdotal evidence suggests that athletes take up to 20 times the therapeutic dose, risking major health concerns [11,18,103,112,127,151-154].

2.8.2.4.3 Current evidence for the effects of HGH on cycling performance

Recent clinical trials have yet to demonstrate the ergogenic effect of HGH on sports performance [11,18,103,112,127,151-154]. Yarasheski et al[155] showed that even when IGF-1 levels were doubled in healthy individuals; there was no effect on the rate of protein synthesis and no increase in muscular strength [4].

Future studies need to investigate the effects of "*stacking*", the combined use of anabolic steroids and HGH on enhancing performance, a practice used by many athletes. The difficulty however lies in obtaining ethical approval for a suitable study, as there are many ethical issues involved in a study of this nature.

The side effects of HGH are well documented in the literature, causing acromegaly, hypothyroidism, diabetes mellitus, water retention and cardiomyopathies [11,18,103,112,127,151-154]. The skeletal changes that occur with acromegaly are irreversible and the artificial administration of HGH may affect normal growth metabolism [13]. In the absence of scientific evidence, the use of HGH as an ergogenic aid to enhance performance cannot be advocated in healthy individuals. Despite this, it is listed as a banned substance by WADA.

2.8.3 Physiological aids

Blood transfusions, EPO and anabolic steroids will be discussed under physiological ergogenic aids. These ergogenic aids will be reviewed as appropriate considering their physiological basis for use, strategies for use in cycling, current evidence for the effects of their use on cycling performance and the health risks associated with their use.

Athletes started blood doping with autologous and homologous transfusions in the 1970s and 1980s with the desire of increasing oxygen transport capacity [13,156]. It was especially popular among endurance athletes, mainly cyclists and runners. Oxygen is carried to dependent tissues, being that of peripheral tissues and muscles, in two ways; dissolved in plasma (3%) or bound to haemoglobin (97%) [157]. Haemoglobin is found within red blood cells (RBC) and is the most important component of oxygen transportation in blood [157,158]. The amount of haemoglobin in the body is consistent with the oxygen requirements and consumption by dependent tissues [158]. As the demand for oxygen increases with exercise, the oxygen-carrying capacity is adjusted to satisfy the increase in demand [158].

Maximum aerobic capacity can be defined as the maximum amount of oxygen that is consumed during exercise [159]. There is a strong relationship between VO_{2max} and haemoglobin mass (the total amount of haemoglobin in the body), which is independent of age and sex [159]. Maximum aerobic capacity is directly related to the delivery and utilization of oxygen, and therefore improvements in the oxygen transport ability may have the potential to increase VO_{2max} and thus enhance athletic performance [159]. The oxygen-carrying protein, haemoglobin, is imperative for success in endurance exercise. The goal of blood doping in endurance sport, is to increase the haemoglobin mass and hence improve oxygen transportation and availability [159].

This ergogenic effect can either be achieved by direct infusion of whole blood or inducing erythropoiesis [127,158,159]. Due to the large effect these practices have shown on oxygen transport, both are banned by WADA [159].

2.8.3.1 Blood transfusions

Administration of packed RBC is used therapeutically in patients with anaemia, and in patients who have lost large amounts of RBC in accidents or as a result of surgery [103,158]. Transfusions may be either autologous or homologous. An autologous transfusion is when blood is donated by an individual and then their same blood is re-infused, whereas homologous transfusion is the infusion of a donor's blood [158].

2.8.3.1.1 Strategies for blood transfusions in cycling

The procedure for autologous transfusion usually involves withdrawing one to four units of blood (one unit = 450 ml). Bone marrow is stimulated as a result of the withdrawal of blood, which stimulates RBC formation [156,157]. Transfusions are done a number of weeks before a competition or event, thus allowing time for the RBC mass to restore to baseline value. Once the blood is withdrawn it is centrifuged, separating plasma from RBC. The plasma is then re-infused immediately and the RBC can either be refrigerated at 4^{o} C (lasting four to five weeks) or frozen at -80^{o} C (lasting several years) [156]. The RBC is then re-infused one to seven days before a competition [157,160]. The ergogenic effect of blood transfusions is well documented, and both haemoglobin and haematocrit levels can increase by 20% when the procedure is properly executed [156,157]. There is, however, a period of reduced performance following blood withdrawal, when the RBC count is low and bone marrow stimulation is being induced [161].

2.8.3.1.2 Current evidence for the effects of blood transfusions on cycling performance

Many studies have been conducted to determine the effect of RBC infusions at rest and during exercise. A recent review by Ekblom[162] found that RBC infusion increased haemoglobin values above the norms and consequently improved VO_{2max}, as well as athletic performance as measured by an increase in time to exhaustion. Gledhill[163] reviewed numerous studies on the effects of blood doping, and found that re-infusion of 900 ml to 1350 ml improved the oxygen carrying capacity of blood, and VO_{2max} by 4% to 9% [163,164].

The transfusion of blood does not come without its risks. Homologous transfusions carry the risk of transmission of blood borne infectious diseases, as well as transfusion reactions [127,158]. This practice is also undesirable as RBC have a long lifespan (three to four months). As a result blood samples taken months after a transfusion can still be detected producing a positive doping test [158]. With the high risks associated with transfusion, as well as the time, intricacies and related storage issues, athletes and coaches have looked at other means of supplying the same ergogenic benefit with less risk [158]. Thus RBC transfusion has largely been replaced by Recombinant Human Erythropoietin (rHuEpo) [11,127,158].

2.8.3.2 Erythropoietin

2.8.3.2.1 Physiological basis for EPO use

The primary regulator of RBC production is EPO. Endogenous EPO is largely synthesized in the kidneys and is produced in correspondence to the amount of oxygen in the blood. Erythropoietin production results in the synthesis of RBC within the bone marrow in a process called erythropoiesis, as well as an increasing haemoglobin and haematocrit [11,127,158]. In 1985 rHuEpo became commercially available when the gene code of EPO was cloned [127,158].

Low doses of rHuEpo increase bone marrow production and thus increase the number of RBC, haemoglobin and haematocrit, as with traditional blood doping (transfusions) [160]. RHuEpo can be administered either subcutaneously or intravenously, with the half-life being relatively shorter when given intravenously [157]. A number of scandals in international competitions have highlighted the use of exogenous EPO. Its abuse as an ergogenic aid by elite endurance athletes is estimated to be 3% to 7%, although some estimate a much higher prevalence, especially among cyclists [157,165].

2.8.3.2.2 Current evidence for the effects of EPO on cycling performance

Many clinical trials have proved the ergogenic effect of rHuEpo on performance, measured by time to exhaustion on a cycle ergometer [166]. Ekblom and Burglund[167] were the first to carry out a clinical trial. They injected 20 $IU.kg^{-1}$ to 40 $IU.kg^{-1}$ of rHuEpo three times per week, over six weeks, and found an increase in haemoglobin and VO_{2max}, which lasted as long as two weeks after the last injection. Lundby et al[166] injected rHuEpo over 15 weeks in healthy recreational males (n=8), and also found an increase in haemoglobin (11.6%) as well as an increase in VO_{2max}. Audran et al[168] examined the effects of rHuEpo by injecting 50 $IU.kg^{-1}$ subcutaneously in trained athletes (n=9), in an incremental cycle test to exhaustion over 26 days.

Maximal aerobic capacity increased by 9% and power output by 7%. Audran et al[168] also showed that the ergogenic effects of rHuEpo lasted several days after the last dose, as did Ekblom and Burglund[167]. Lippi et al[157] had similar results to the aforementioned studies with rHuEpo administration increasing haemoglobin, haematocrit and VO_{2max}.

Lippi et al[157] also found that the effects of rHuEpo lasted longer, with values only returning to baseline one month after the last dose. A double-blinded study conducted by Parissotto et al[169] found similar results to all of the above mentioned studies, with a 7% to 12% increase in haemoglobin mass and a 6% to 7% increase in VO_{2max}. The literature clearly demonstrates the ergogenic effect of rHuEpo on endurance performance by increasing oxygen transportation and availability. Table 2.4 provides a summary of relevant experimental studies that assessed the ergogenic effects of blood doping on cycling performance [166,168-171].

In addition to rHuEpo there are a number of other methods that are being used to increase haemoglobin, oxygen transportation and performance [160,161,172]. There are several EPO analogues available [79]. Darbepoetin is one such example, which is used medically in the treatment of chronic renal failure [79]. Darbepoetin has a longer half-life than rHuEpo and thus can be administered less often, however it is easier to detect [103,161]. Potential side effects of rHuEpo and EPO analogues may include hypertension, thromboembolic events and seizures. Increased thromboembolic events occur as there is an increase in viscosity of the blood due to an increase in the number of packed RBC [18,103,157,159,173].

The ergogenic effects of blood doping through blood transfusions and EPO are well documented [164,168-171]. Due to the high risks of blood transfusions and the intricacies involved, the popularity of EPO has increased [164,169]. Recombinant human erythropoietin increases haemoglobin levels, haematocrit and VO_{2max}, and thus significantly enhances endurance cycling performance [157,167-169].

Table 2.4: Summary of experimental studies that assessed the ergogenic effects of blood doping on cycling performance.

Article	Study design	Sample size (n)	Participants	Intervention	Exercise protocol	Results	Conclusion
Thomsen et al[170]	Single-blinded (control group only), placebo-controlled design LOE: II	16 participants (males)	Healthy volunteers	-PLA group (saline) vs. rHuEPO (60 IU.kg^{-1}) of rHuEpo -First 2 weeks, one injection every second day; -Third week, three injections on three consecutive days; -Week 4 to 13, one injection every week	-The protocol was done pre-trial, at 4 weeks and at 11 weeks: -Incremental bike ride until fatigue at VO_{2max} followed by, -TTF at a given percent of the maximum attained work-load during the incremental exercise test -At 11 weeks there was an additional TTF trial	-With rHuEpo treatment , VO_{2max} increased by 9.1 % and 8.1% in week 4 and 11 respectively ($p < 0.05$) (no changes in the PLA group) -TTF in the rHuEpo treatment group was increased by 54.0 % and 54.3% after 4 and 11 weeks of treatment ($p < 0.05$)	rHuEpo significantly prolonged TTF in healthy non-athlete subjects. The administration of rHuEpo provides an ergogenic effect by prolonging submaximal cycling performance by about 54%.
Lundby et al[166]	Case series LOE: IV	8 participants (males)	Recreationally active varsity students	-5,000 IU of rHuEpo was injected during the first 2 weeks, one injection every second day; -three injections on 3 consecutive days in the third week; and -Week 4 to 15, one injection every week	-Cycle to fatigue with incremental increases in load -Tests were completed before rHuEpo administration (pre-rHuEpo), as well as after week 13	-rHuEpo increased Hb by 11.6% and VO_{2max} increased by 300 ml -Maximal workload was also significantly increased from pre- to post rHuEpo administration ($p < 0.05$)	rHuEpo exerts its main effect on VO_{2max} through an increase in RBC mass. The ergogenic effect of rHuEpo on VO_{2max} can be explained through the enhancement of the oxygen-carrying capacity of blood.

KEY: PLA: placebo; rHuEPO: Recombinant Human Erythropoietin; VO_2max: maximal aerobic capacity; TTF: time-to-fatigue; Hb: haemoglobin.

Table 2.4 (continued): Summary of experimental studies that assessed the ergogenic effects of blood doping on cycling performance (continued).

Birkeland, Stray-Gundersen, Hemmersbach, Hallen, Haug & Bahr[171]	Randomised, double-blind, placebo-controlled design LOE: I	20 participants (males)	Well trained athletes (cycling, orienteering, running, triathlon, swimming, and cross-country skiing)	-5,000 IU of rHuEPO (n=10) vs. PLA (n=10) three times weekly for 30 days -Participants were followed for a period of 4 weeks thereafter	-Cycle test: TTF with an incremental workload maintaining a cadence of 85 rpm to 95 rpm	-VO_{2max} increased by 7% post rhEPO administration ($p = 0.001$) (no change in PLA group) -TTF increased from 12.8 min at baseline to 14.0 min 1 day post-treatment in the rHuEPO group ($p < 0.0001$)	VO_{2max} and TTF were significantly increased for up to 3 weeks post-administration, which indicates an ergogenic effect on endurance performance. This study also showed a performance advantage for at least 2 weeks longer without than any indication of rHuEPO use in blood samples.
Parisotto et al[169]	Double-blind design, placebo-controlled design (Randomisation not mentioned) LOE: II	27 participants (22 males and 5 females)	Healthy volunteers	-5 weeks of preliminary training followed by 25 days of rHuEPO (n=18) vs. PLA (saline) (n=9) administration -50 $IU.kg^{-1}$ (3 x week)	-Total Hb mass and VO_{2max} were determined 1 week prior to rHuEPO administration, within 3 days after the last injection and at the end of wash-out (on a treadmill or cycle ergometer)	-Relative to baseline the rHuEPO group showed a significant increase ($p < 0.05$) 7% to 12% in Hb mass (PLA group unchanged) -VO_{2max} increased by 6% to 7% from baseline in the rHuEPO group	This study shows an ergogenic effect of rHuEPO administration in enhancing sporting performance, lasting up to 4 weeks after cessation of use.
Audran et al[168]	Case series LOE: IV	9 participants (7 males and 2 females)	Trained athletes	-rHuEpo administered (50 $IU.kg^{-1}$) for 26 days	-Incremental exercise cycle test to fatigue -The tests were performed 2 to 3 days before rHuEpo administration to determine baseline values and the first week after the last drug intake	-VO_{2max} and PO were significantly higher after 26 days of rHuEpo administration than at baseline	Repeated doses of rHuEpo administered to normal athletes stimulated erythropoiesis, therefore providing an ergogenic effect in cycling performance.

KEY: PLA: placebo; rHuEPO: Recombinant Human Erythropoietin; VO_2max: maximal aerobic capacity; TTF: time-to-fatigue; min: minutes.

2.8.3.4 Anabolic steroids

Since 1935, when testosterone was first discovered, many derivatives of testosterone have been synthesized and developed to improve its efficacy [174]. Testosterone can have both androgenic and anabolic effects. Growth of the male reproductive system and secondary sexual characteristics is a result of the androgenic effects, whereas increased protein synthesis is a result of the anabolic effects of testosterone [174].

2.8.3.4.1 Physiological basis for anabolic steroid use

The widespread use of anabolic-androgenic steroids (AAS) manifests from the myotrophic action, resulting in enhanced muscle size, strength, power and thus performance [66,144,174]. Anabolic-androgenic steroids are effective in three principal ways [174]. Firstly, AAS increase protein synthesis in skeletal muscle at a cellular level. The AAS bind to androgen receptors, which in turn stimulates gene transcription and the production of mRNA, ultimately inducing protein synthesis [174]. Secondly, AAS block the catabolic effects of gluco-corticosteroids during intense and stressful training or competition [174]. Lastly, the ingestion and injection of AAS results in states of ecstasy and diminished feelings of fatigue [174]. Subsequently, athletes using AAS can train more frequently and at the required intensity, as recovery between training sessions and from competition is increased [174].

Anabolic-androgenic steroids are mostly used by athletes in power sports (e.g. weightlifting). However, anecdotally they are reported to be used among a number of other sporting codes in which athletes seek to improve strength and appearance [66]. The exact quantification of the effect of AAS on performance is not possible to evaluate. A double-blind study would be ethically impossible [66]. The mechanisms of action of AAS are well understood and the numerous side effects, although variable are well documented [66]. Possibly the key motive for its use amongst cyclists would be to allow for more intensive training by increasing the rate of recovery [65].

The use of AAS is not limited to professional athletes. Recently there has been an increase in use amongst young athletes and non-athletes alike; trying to improve body physique and recreational sporting performance [174]. Anabolic-androgenic steroids are easily available on the black market and in training centres. As a result it is a highly accessible drug and therefore one of the most commonly misused drugs in sport [66,144,174]. Most athletes using AAS either do so using the "*stacking*" method (using two or more AAS) or "*cycling*" method (a six to ten week cycle of use, followed by a similar period in which no AAS are taken) to help reduce the side effects [66,144,174].

The main side effects of AAS include cardiovascular risk factors (increased blood pressure and cholesterol levels), acne, increased body hair, aggressive behaviour, irritability, mood disorders, sleeplessness and decreased fertility [66,144,174]. The prevalence of use of AAS among cyclists is unknown and generally based on anecdotal evidence and speculation.

Anabolic steroids are effective for increasing muscle size, power and strength when an athlete is involved in a resistance training programme. Anabolic steroids do not improve $VO_{2max,}$ but may have the potential to improve endurance performance by increasing power output [13]. Evidence supporting the effectiveness of AAS as an ergogenic aid in endurance cycling performance is limited.

2.9 INSTRUMENTATION TO DETERMINE THE USE OF ERGOGENIC AIDS

It is difficult to know the extent of doping; worldwide it is a controversial area of sports medicine [8,9,103]. Only a handful of studies have reported the incidence of doping amongst cyclists [7-9]. Methods of data collection have included anonymous self-reported paper questionnaires and personal interviews [6,7,9].

One of the major biases to consider when administering a questionnaire or conducting an interview is social desirability. This refers to the tendency by respondents to give more socially desirable answers to questions; "*faking good*" [175]. This generally involves giving answers that make a good impression or conceal sensitive information [175]. Less distortion of social desirability was found in computerised questionnaires compared to paper-based questionnaires and interviews [176]. This was especially seen when participants could backtrack to questions and were alone when completing the questionnaire. When anonymity was assured, participants also gave reduced social desirability distortion with computerised questionnaires compared to paper-based questionnaires and interviews [176]. This was particularly seen when sensitive information or personal behaviour was being assessed [176]. The presence of another person in the form of a test administrator or interviewer may obviate assertions of anonymity. Participants may be inclined to have a greater sense of confidentiality and neutrality when completing a questionnaire alone in their own time [175].

The presence of a test administrator or interviewer may reduce neutrality and provoke evaluation apprehension. However, interviews are still used to gather this highly sensitive information of doping and ergogenic aid use. The advantage of interviews is that they reduce non-responses and allow for more elaborate answers [175]. Petroczi[7] investigated doping behaviour and attitudes through a series of psychological tests and self-reported questionnaires in college athletes (n=174). Due to the sensitivity of the subject Petroczi[7] emphasized that there was a high rate of under-reporting.

Over the years there has been an increase in the number of studies using internet and email to collect data for research. However the response rates of internet studies are decreasing causing doubt in this method of data collection [177]. Sheehan[177] reported a mean response rate of 36.8% for email surveys, while Cook, Heath and Thompson[178] suggested that a response rate of 25 to 30% from email surveys is more likely. The response rates to email and online surveys may have a number of potential influences [177,179].

With regards to survey length, the literature is conflicted and more research is required to make direct inferences [177]. With the increase in the amount of online survey research being conducted, the number of requests sent to individuals to complete surveys has increased [177]. As a result individual's attitudes may be unfavourable towards surveys, which may lower response rates [177]. Poorer response rates may also be related to the participant's perception of the mail as "*junk mail*" or that the email contains a virus [179]. Participants' concerns regarding confidentiality of data and privacy may too decrease response rates [180]. Evans and Mathur[179] suggest clearly defined policies of confidentiality and statements as to what data will be used for to help decrease possible refusal of participation.

Research has identified the benefits of email surveys over paper surveys, particularly with regards to cost, flexibility and speed efficiency [177,178,180]. The internet allows for online surveys to be speedily distributed nationally or internationally within a short time period [179]. Online surveys are very flexible as they accommodate for customised language selection, as well as allowing participants to view only questions applicable to them [179]. Online surveys also provide researchers with the opportunity of manipulating questions. Questions are manipulated to ensure participants answer the questions before being able to advance, which assists in decreasing non-responses [179]. The quality and success of a survey depends not only on a sufficient sample size, but also on fully completed responses [180]. The low cost of data collection also allows for greater sample sizes, therefore producing better results with more statistical power [177].

The use of questionnaires as a study method may be considered weak. It is recommended in the literature that combinations of quantitative measures are employed, for example biomedical tests, interviews and questionnaires [181]. The purpose of a descriptive study is to discover information about a specified population. It provides information on the magnitude of a problem within a defined population. Descriptive research is often the starting point of other research, as it provides information on what to further investigate, how to further investigate it and helps to formulate testable hypotheses [182].

Considering the sensitive nature of the topic under investigation, an online questionnaire was developed to collect data as defined in the literature and as stated in the aim of this study as set out in Section 1.2.2 (page 2). It was highlighted earlier that the risk of under-reporting in questionnaires is one of the limitations of a study of this nature. However, information gathered through anonymous self-administered questionnaires has demonstrated to be reliable [6]. A key variable effecting data collection and data quality are assurances of anonymity and confidentiality [175,176]. This has shown to be enhanced through the use of questionnaires compared to interviews [176]. The use of a questionnaire to collect data has the benefits of reduced costs, time and most importantly for this study, a larger sample size. Interviews are highly time consuming, require specific skills by the interviewer, are expensive and generally can only reach a small sample size. An online questionnaire was used specifically for the reasons as stated above, and the suggestion from Evans and Mathur[179] related to clearly defined policies of confidentiality and transparency for the data was employed in this study.

2.8 SUMMARY OF THE LITERATURE

With the mounting popularity of cycling in South Africa, and the increasing emphasis on athletic performance, it is unlikely that the use of ergogenic aids will decrease [2,19]. Cyclists and coaches are consistently looking for that competitive edge, and it is often found that athletes will be "*ten steps ahead*" of science when it comes to the next best ergogenic aid [153]. Important components of endurance cycling include training, fatigue and recovery. Consideration of the potential factors limiting training and natural performance enhancement may suggest that ergogenic aids are not restricted to professionals.

Factors influencing the prevalence of ergogenic aids amongst athletes depend on three sport specific elements, namely: the type of sport, whether it is a team or individual sport, and whether the sport is endurance or high intensity in nature [6,57].

Current literature has revealed that the most frequently used ergogenic aids among cyclists are sports drinks, vitamins, amino acids, caffeine, PRO, and NSAIDs [6,57].

Across the literature, it has been shown that there is difficulty in quantifying the degree to which doping practices are common [66]. The use of both legal and illegal/banned ergogenic aids is generally concealed behaviour. This limits findings of true incidence rates [66,8,9]. This surreptitious behaviour makes it hard to present clear evidence on the short term and long term adverse health effects of specific ergogenic aids [66]. The consumption of a variety of products by athletes also makes it hard to provide clear evidence for the adverse health effects [66].

There are well-documented roles for CHO, caffeine, blood transfusions and EPO in enhancing performance in endurance cycling. An ergogenic effect was also observed in short duration high-intensity cycling performance mimicking time trials, with these aids. The evidence supporting the benefit of other popular ergogenic aids on cycling performance was equivocal and inconclusive. A major limitation across the literature was the lack of standardised exercise protocols when investigating the true effect of specific ergogenic aids on cycling performance. Future research must develop standardised measurement outcomes and protocols that stimulate real life competitions, so that studies can be compared and sound inferences can be made.

The prevalence of use and practices in South African cyclists are unknown and yet to be examined. Research is needed to gain information and knowledge as to which ergogenic aids South African cyclists are using, before we can investigate beliefs and knowledge of doping. Research of this nature is needed to understand the magnitude of doping, as well as the actual intake of nutritional and pharmacological ergogenic aids. In addition, the intake of legal ergogenic aids may increase the likelihood of subsequent doping [6]. Effective anti-doping strategies should be planned and based on the consideration of a possible relationship between frequency and usage patterns of all ergogenic aids [1]. This study will provide the first step in gathering information on usage patterns of ergogenic aids in South African cyclists. For all aforementioned reasons, this study and future studies are strongly warranted and needed to help bridge the gap between science and cycling.

Therefore the aim of this study was to describe the use of ergogenic aids in South African cyclists during training and competition. For this purpose, usage patterns of both legal and illegal/banned ergogenic aids were surveyed within a sample of cyclists through an anonymous online questionnaire.

CHAPTER 3: THE USE OF ERGOGENIC AIDS IN CYCLISTS

3.1 INTRODUCTION

Athletes often use ergogenic aids in an attempt to improve performance and address the negative stresses resulting from high intensity exercise [15,16,183]. There are a number of different types of ergogenic aids, of which the pharmacological and physiological aids have received the most attention in cycling over the last decade [17,18]. Within the three broad categories of nutritional, pharmacological and physiological ergogenic aids there are both legal and illegal/banned substances. The banned substances are those mostly classified under physiological ergogenic aids and include anabolic steroids, blood transfusions, EPO, HGH and cortisone [11].

The estimated prevalence of ergogenic aid use amongst international athletes across "*all sports*" ranges from 46% to 100% [6,53,55,64]. However, these data are generic rather than focused specifically on cycling. There are few studies reporting the prevalence of use specifically within cycling. A 10.3% to 17.5% prevalence of doping was reported by one study that included cyclists from a recreational level of participation to an international level [10]. It is difficult to determine the scale of ergogenic practices, due to the sensitive nature of the research [66]. It is therefore thought that the prevalence is much higher than that reported in the literature. The use of ergogenic aids in South African cyclists has not been determined. A good understanding of prevalence of use of ergogenic aids and factors influencing choices is necessary to facilitate safe participation in sport, to promote drug-free sport, to identify educational needs, and the needs of other forms of interventions.

Therefore the current survey was performed to assess information regarding the current use (last 12 weeks) of nutritional, pharmacological and illegal/banned ergogenic aids amongst South African cyclists. The aim and specific objectives of this dissertation have been described in Section 1.2.2 (page 2).

3.2 METHODS

3.2.1 Study design

The study had a descriptive correlational design. Participants were recruited through electronic correspondence and cycling-specific media platforms. All participants were required to provide informed consent prior to completing the questionnaire (Appendix I).

3.2.2 Participants

3.2.2.1 Inclusion criteria

Participants included male and female cyclists between 18 and 65 years of age. Participants were required to meet at least one of the following criteria to be included in the study: a minimum of two years history of competitive cycling[*]; a minimum average mileage of 80 km.wk^{-1}; cycling for at least six months out of 12 months in a year; and/or the completion of at least three cycling races in the last six months [(34)].

3.2.2.2 Exclusion criteria

Novice cyclists were excluded from the study. Participants with diabetes mellitus, eating disorders and any metabolic disorders were also excluded from the study, because these conditions may have limited or influenced nutritional choices [(88)]. Participants who failed to complete more than 30% of the questionnaire were excluded from the study. By failing to complete more than 30% participants did not reach Section C: the use of ergogenic aids (page 9 of the online questionnaire). In addition, participants who did not provide informed consent on FluidSurveys© were not able to access the questionnaire, and were thus excluded from the study.

[*]Competitive cycling was defined according to the following race times; (i) Cape Argus Pick 'n Pay Cycle Tour (109 km): male-sub 3h15m, female-sub 3h30m, (ii) Momentum 94.7 Cycle Challenge (94.7 km): male-sub 2h45m, female- sub 3h00m, and/or (iii) Amashova Durban Classic (106 km): male-sub 3h00m, female- sub 3h15.

3.2.2.3 Sample size determination

In the absence of more definitive data regarding the use of ergogenic aids by cyclists, the prevalence of supplement use in athletes was used to calculate the required sample size for the study. An expected frequency of 60% was selected based on previous studies, which report the incidence of supplement use of between 45% and 85% [180,184]. If the worst expected frequency was 55%, with confidence intervals (CI) of 80%, 90% and 95%, the required sample size was 140, 211 or 276 participants respectively. It is recognised that response rates for questionnaire-based studies are often less than 56% [185]. Therefore to ensure sufficient statistical power approximately 552 participants needed to be recruited for this study. A total of 467 questionnaires were returned of which 260 were excluded from final analyses. The details for exclusion are discussed further in Section 3.3.1 (page 74). The final sample size for this study was 207 participants.

3.2.2.5 Recruitment

A web-based search for contact details of cycle clubs, shops and online forums in South Africa was performed. Google was searched using the keywords: "*cycling*", "*South Africa*", "*cycling clubs*", "*cycling shops*" and "*cycling forums*". Club chairman's and cycle shop managers were informed electronically or telephonically of the study, and permission was requested to distribute the link and study information on mailing lists or in club newsletters (Appendix II). The cycling clubs and shops were sent two email reminders over the time the questionnaire was available on FluidSurveys© (22 April 2013 to 18 August 2013). Table 3.1 reflects the provincial distribution of cycling clubs and shops (n=58) that were contacted regarding the study. In addition, five online media platforms hosted the questionnaire link for the entire duration of the study. The five forums included: The hub (www.thehubsa.co.za), Warthog Google Group (warthogs-mtb-sa@googlegroups.com), Bicycling Magazine (www.bicycling.co.za), Cycle lab Facebook (www.facebook.com/pages/Cycle-Lab/) and Cycle Lab Western Cape twitter (@CycleLabWC). The researcher sent reminders to the media platforms ensuring the questionnaire link was re-posted twice in each forum over the duration of the study.

Table 3.1: Summary of the provincial distribution of cycling clubs and shops (n=58) that were contacted.

Province	Number of clubs and shops contacted
Western Province	n=22 (38.0%)
Gauteng	n=9 (15.5%)
Free State	n=1 (1.7%)
KwaZulu-Natal	n=13 (22.4%)
Limpopo	n=2 (3.4%)
Mpumalanga	n=4 (7.0%)
Eastern Cape	n=5 (8.6%)
Northern Cape	n=1 (1.7%)
North West	n=1 (1.7%)
Total	**n=58 (100.0%)**

Based the on poor response rate to the above two recruitment methods, the recruitment method was amended after two months. Ethics approval for the amendment was obtained from the University of Cape Town, Faculty of Health Sciences Human Research Ethics Committee (HREC). Participants were also then recruited from a database of race participants who completed a previous cycling questionnaire regarding race goodie bags from the Cape Argus Pick 'n Pay Cycle Tour. Participants voluntarily gave their contact details and residing province to this database, and gave unrestricted permission to be contacted about cycling-related events or activities. The list consisted of 3378 national and international email contacts. One hundred and twenty one participants were excluded as they were international cyclists. Of the remaining 3257 contacts, approximately 20 emails per 100 sent were unsuccessful, due to failed deliveries. Therefore, approximately 2605 cyclists were contacted individually with the link requesting their participation in the study. The Western Cape, Gauteng and KwaZulu-Natal were the top three provinces in which cyclists resided.

3.2.3 Measurement instrument

3.2.3.1 Ergogenic aids questionnaire

A self-developed questionnaire was designed to obtain information regarding the use of ergogenic aids in cyclists during training and competition, as well as to determine cyclists' pattern of use and the perceived effect of ergogenic aids (Appendix III). The prologue to the questionnaire included participant information, informed consent and training screening questions (inclusion criteria). Participants were excluded from the study if they did not give informed consent or meet the training criteria. The questionnaire comprised of three sections following the prologue. Section A assessed demographic information and included a brief medical screening. Participants were excluded from the study if they had any medical disorders. Section B assessed training and competition history, and Section C investigated the current use of ergogenic aids in cyclists. Section C was based on commonly reported ergogenic aids used in cycling in current literature [9,17], as well as WADA's prohibited list [62]. The ergogenic aids which the questionnaire included were both legal and illegal substances. Table 3.1 and Table 3.2 provide a summary of the questions asked in Section A and Section B of the questionnaire respectively. Table 3.3 provides a summary of questions asked in Section C for each ergogenic aid. Participants were required to complete all parts of Section A and Section B. In Section C, participants were required to indicate which ergogenic aids they were currently using (over the last 12 weeks) from a list provided. The list of ergogenic aids were not categorised into groups, they were listed in a random order. Based on participants' individual selection, the online questionnaire automatically redirected participants to detailed questions regarding the self-reported ergogenic aids.

The questionnaire was posted online via FluidSurveys©. FluidSurveys© is a Canadian-developed online questionnaire software programme, which enables users to develop surveys to collect and analyse data. Participants were able to access the questionnaire via a link (http://fluidsurveys.com/surveys/ergogenic_aids/copy-the-use-of-ergogenic-aids-by-cyclists/langeng/)*. FluidSurveys© provided easy to use steps, allowing participants to answer all required and relevant sections, whilst skipping irrelevant sections. The questionnaire was available in English and Afrikaans. The questionnaire was forward-and back-translated to ensure content, technical and semantic equivalence. The ethical issues relating to the privacy, confidentiality and anonymity of data collected in this study are discussed in Section 3.2.6 (page 72).

*It is not possible to access the questionnaire via this link anymore, as the FluidSurveys© account was closed once data collection had been completed.

Table 3.1: Summary of the Training Screening Section, and Section A of the questionnaire.

Prologue: training screening **(If participants did not meet the training inclusion criteria they were excluded from the study.)**
Q.1 Please indicate for which criteria you qualify for below:
A.1 Have been cycling competitively for at least two years
A.2 Currently cycle a minimum of 80 $km.wk^{-1}$
A.3 Cycle for at least six months out of the year
A.4 Have participated in at least three cycling races/events in the last six months
A.5 Not applicable (N/A)
Section A: demographic information
Q.1 Gender
Q.2 Age
Q.3 Height (m)
Q. 4 Weight (kg)
Q.5 Highest level of education
medical screening **(If participants had any of these medical disorders they were excluded from the study.)**
Q.1 Do you suffer from any of the following conditions?
A.1 Diabetes Mellitus
A.2 Any metabolic disorder (specify)
A.3 An eating disorder
A.4 N/A

Table 3.2: Summary of Section B of the questionnaire.

Section B: training and competition history **(As applicable over the last 12 week period.)**
Q.1 Type of event/s you participate in?
Q.2 Which is your preferred event?
Q.3 Are you currently cycling competitively?
Q.4 How many years have you been cycling competitively?
Q.5 In which year did you start competitive cycling?
Q.6 On average how many times do you cycle per week?
Q.7 On average how many hours do you cycle per week?
Q.8 On average how many kilometers do you cycle per week?
Q.9 How many of your rides per week would you classify as hard rides (>75% HR_{max})?
Q.10 How many one-day events have you completed in the last 12 weeks?
Q.11 How many multi-day events have you completed in the last 12 weeks?
Q.12 What is your best race time for the following races (list provided), and when did you achieve this time (year)?
Q.13 How many days after a race (80 km to 100 km) would you resume normal training?
Q.14 How many days after a multi-stage race/event would you resume normal training?

Table 3.3: Summary of Section C of the questionnaire. Note: the shaded blocks represent the questions which were asked for each ergogenic aid. The un-shaded blocks indicate that the question was not asked for that particular ergogenic aid.

Section C: Ergogenic aids (As applicable over the last 12 week period.)																	
	Caffeine	**Blood transfusion**	**Creatine**	**Vitamin B**	**Sports drinks/gels**	**Amino acids**	**EPO**	**Anabolic steroids**	**CHO**	**PRO**	**CHO & PRO**	**NSAIDS**	**Analgesics**	**Electrolyte**	**HGH**	**Cortisone**	**Other**
When do you use it?																	
How many years have you been using it?																	
How do you administer it?																	
How many times a year do you use it?																	
Do you have help administering it?																	
Does it improve your performance?																	
How do you think it works?																	

Table 3.4 (continued): Summary of Section C of the questionnaire. Note: the shaded blocks represent the questions which were asked for each ergogenic aid. The un-shaded blocks indicate that the question was not asked for that particular ergogenic aid.

	Caffeine	**Blood transfusion**	**Creatine**	**Vitamin B**	**Sports drinks/gels**	**Amino acids**	**EPO**	**Anabolic steroids**	**CHO**	**PRO**	**CHO & PRO**	**NSAIDS**	**Analgesics**	**Electrolyte**	**HGH**	**Cortisone**	**Other**
If you did not use it, would your performance deteriorate?																	
Which product do you use most frequently?																	
What do you use it for?(therapeutic reasons/performance)																	
How soon after training or competition do you start ingesting it?																	
Do you eat a specific amount according to your body mass?																	
What form of CHO are you ingesting?																	

Table 3.4 (continued): Summary of Section C of the questionnaire. Note: the shaded blocks represent the questions which were asked for each ergogenic aid. The un-shaded blocks indicate that the question was not asked for that particular ergogenic aid.

	Caffeine	**Blood transfusion**	**Creatine**	**Vitamin B**	**Sports drinks/gels**	**Amino acids**	**EPO**	**Anabolic steroids**	**CHO**	**PRO**	**CHO & PRO**	**NSAIDS**	**Analgesics**	**Electrolyte**	**HGH**	**Cortisone**	**Other**
If you use refined* CHO, please indicate which kind.																	
If you use nutrient dense CHO, please indicate which one.																	
What form of PRO are you ingesting?																	
If you use liquid PRO, please indicate which kind.																	
If you use lean PRO, please indicate which one.																	

*Participants were asked specific questions concerning the type/form of carbohydrate and protein consumed.

Table 3.4 (continued): Summary of Section C of the questionnaire. Note: the shaded blocks represent the questions which were asked for each ergogenic aid. The un-shaded blocks indicate that the question was not asked for that particular ergogenic aid.

	Caffeine	**Blood transfusion**	**Creatine**	**Vitamin B**	**Sports drinks/gels**	**Amino acids**	**EPO**	**Anabolic steroids**	**CHO**	**PRO**	**CHO & PRO**	**NSAIDS**	**Analgesics**	**Electrolyte**	**HGH**	**Cortisone**	**Other**
How would you best describe your preparation leading up to a race (5 days)?																	
How many tablets per dose?																	
How many doses per day?																	
How many days will you continue to take it for?																	
Please rank your top three sources of information influencing your use of it?																	

3.2.3.2 Validity of the ergogenic aids questionnaire

A panel of three experts, with special interests in cycling, reviewed the questionnaire to ensure content and construct validity. The expert validators were selected based on their expertise and reputation in the field of endurance sport. The validation panel consisted of a sports physician and South African cycling coach, a sports dietician, and a sports physiotherapist. Once ethical approval was granted, the validators were contacted requesting their assistance in validating the questionnaire (Appendix IV). The validators were requested to comment on the relevance and importance of the questions and whether the questions were clear and easy to understand. In addition, the validators were requested to give input regarding potential questions or sections that had not been included, and that may contribute to addressing the study objectives. The validators were asked to complete the review of the questionnaire within a four-week period. All three experts returned the questionnaires. The researcher and supervisors reviewed and consolidated the feedback from the three validators, and compiled an updated version of the questionnaire. Feedback was predominantly related to aspects of language simplification of questions as well as the inclusion of contact details for the researcher, supervisors and the HREC. There was no conflicting feedback from the validation panel. The panel of experts all indicated that the questionnaire was thorough and covered all components of the study objectives. The revised questionnaire was sent back to the validators for final approval before the feasibility study.

3.2.3.3 Feasibility of the ergogenic aids questionnaire

Feasibility of the questionnaire was established with a feasibility study that consisted of seven cyclists who met the inclusion criteria for the study. The participants were required to comment on the comprehension of the questions and the ease of completion of the online questionnaire. All seven participants completed the questionnaire successfully, making multiple or numerically ranked selections where applicable. Feedback was obtained from all participants regarding the comprehension of the questionnaire and the potential difficulty in navigating through the online questionnaire. Changes as a result of feedback mostly included technical aspects concerned with the online survey programme itself. Firstly, the automatic redirecting of participants to more detailed questions regarding the use of ergogenic aids had to be corrected. Participants were only required to answer questions on their self-reported use of ergogenic aids. Secondly, participants had to rank their top three sources of information associated with their use of any particular ergogenic aid. This ranking question had to be revised so that each number could only be selected once to accurately rank sources of information.

The final change was the inclusion of metric measurements (ml) concerning fluid intake before, during and after competitions. Participants' responses from the feasibility study were not included for data analysis of the main study.

3.2.4 Procedure

Once the questionnaire was validated and the feasibility study completed, participants were contacted through electronic or telephonic correspondence informing them of the purpose of the study, and requesting their participation. Respective cycling clubs, shops, media platforms and individual participants were then emailed the link to the questionnaire available on FluidSurveys© (Appendix II). Only participants that indicated that they understood the study information and were willing to take part in the survey (informed consent) were able to progress to the next stage of completing the questionnaire. Participants who did not meet the training criteria after giving informed consent were excluded from the study. Participants were asked to self-report medical history in a screening question, before accessing Section B and Section C of the questionnaire. Participants who were excluded based on screening information (training criteria and medical history) were redirected to an exit window within the online survey. No personal information was requested to ensure the anonymity of participant responses. On completion of the questionnaire, participants were thanked for their time and response. Cycling clubs and shops were sent two email reminders over the time the questionnaire was "*live*" on FluidSurveys© (22 April 2013 to 18 August 2013). Reminders to the media platforms were sent, ensuring the questionnaire link was reposted twice in each forum over the duration of the study.

3.2.5 Statistical analyses

Statistical analyses were performed using Statistica software (StatSoft, Inc. 2004) STATISTICA (Data analysis software system, version 11, www.statsoft.com). Pearson's chi-square measures of association and percentages were used for categorical data, for example; gender, level of education, competitiveness, preferred cycling event and the self-reported use of ergogenic aids. Independent t-tests were used for all numerical data. Numerical data presented as the mean and standard deviation (X ± SD) were age, stature, body mass and body mass index (BMI). Average weekly mileage, number of training rides per week and the number of recovery days taken after an event are presented as the number of responses (n) and percentages (%).

Forward stepwise analyses in IBM SPSS Statistics (version 21, 2012) were performed to predict the probability of participants using a specific ergogenic aid. The predictor (independent) variables were age, BMI, education, preferred cycling event, cycling competitively, average weekly mileage (km.wk^{-1}), number of times a participant cycled per week (frequency) and the number of recovery days post competition (80 km to 100 km).

The predictor variables were coded as seen in Table 3.5. Regression analyses were performed on all ergogenic aids except for illegal/banned aids due to the small response rate relating to the use of these aids. All variables were entered simultaneously, CIs were 95% and statistical significance was accepted as $p < 0.05$. All of the forward stepwise regression tables show the odds ratio (Exp(B)), p-values, 95% CIs and the Wald test for each of the predictors. The Wald test is used to test the significance of the variable based on the sample estimate [186].

Table 3.5: Predictor variables coded for forward stepwise regression analyses.

Predictor variable	Coded 1	Coded 0
Age (years)	≥40	≤39
BMI	≥25	18.2 to 24.9
Education	≥Grade 12	≤Grade 11
Preferred event	Road cycling	Mountain biking
Cycle competitively	Yes	No
Km.wk^{-1}	≥120	≤119
Frequency per week	≥4	≤3
Recovery days post competition	≤three days	≥Four days

3.2.6 Ethical considerations

The study was performed in accordance with the principles of the Declaration of Helsinki (Seoul version, 2008*. The study was submitted and approved by the Faculty of Health Sciences Human Research Ethics Committee, University of Cape Town (HREC REF: 255/2012) (Appendix V). Ethics approval was obtained prior to the commencement of any research-related activities. Participants were required to give informed consent before taking part in the study.

*The researcher is aware that there is a new version of the Declaration of Helsinki (Brazil, 2013); however the current research was conducted prior to the release of the 2013 version.

The first page of the online questionnaire provided the participants with information regarding: the purpose of the study; the risks and benefits of the study; how privacy, confidentiality and anonymity would be maintained; voluntary participation and the right to withdraw from the study at any time while completing the online questionnaire (Appendix I).

Participants were required to check a box indicating that they understood the study information and were willing to take part in the survey to progress to the next stage of completing the questionnaire. Participants that did not provide consent were unable to access the questionnaire and were automatically redirected to an exit window on the questionnaire site. Once participants had completed the questionnaire they could not withdraw consent. Participants' responses could also not be withdrawn once submitted. The online questionnaire was completely anonymous. This was a feature of FluidSurveys© software design that was purposefully selected for this study. As a result all referring uniform resource locators (URLs) and internet protocol (IP) addresses of respondents were hidden. It was therefore not possible for responses to be traced back to individual respondents. Once all the responses were received and the online survey was closed, responses were numerically coded. The data were strictly confidential, and only the principal researcher and primary supervisor had access to the data. There were no hard copies of the data. All data were securely stored on one password-protected laptop.

3.2.6.1 Risks to the participants

There were no risks to the participants, as no physical testing was carried out. Due to the sensitive nature of the questionnaire inquiring the use of both legal and illegal ergogenic aids, information obtained from the questionnaires was not forwarded to any regulatory body, such as the South African Institute for Drug-Free Sport (SAIDS) and South African cycling. This was clearly stated in the participant information sheet on the first page of the online questionnaire.

3.2.6.2 Benefits to the participants

There were no direct benefits to participants for taking part in this study. It was not possible to provide participants with feedback about the study due to the completely anonymous nature of the questionnaire. A small minority of participants contacted the researcher independently stating that they would be interested in the results of the study.

Online Bicycling Magazine also requested feedback about the study with intention to write a feature story. Feedback to those participants who were interested in the results and to the online Bicycling Magazine will be given once the dissertation has been examined.

3.3 RESULTS

3.3.1 Participants

The questionnaire was available on FluidSurveys© from the 22 April 2013 until 18 August 2013. Four hundred and sixty-seven responses were received. Figure 3.1 shows a summary of the study sample. Of all the responses received, 78 did not qualify for the study. Participants did not qualify as a result of not providing informed consent, failing to meet the training and medical screening criteria or they did not use the ergogenic aids listed. A further 182 participants were excluded, although having qualified, as they did not complete more than 30% of the questionnaire. By failing to complete more than 30%, participants did not reach Section C: the use of ergogenic aids (page 9 of the online questionnaire). Therefore a total of 207 participants qualified and were included in the analyses. The average completion time was 28.5 ± 32.2 minutes for males and 20.5 ± 11.7 minutes for females. There was no significant difference in completion time between male and female participants. Although the questionnaire was available in both English and Afrikaans, no Afrikaans responses were received.

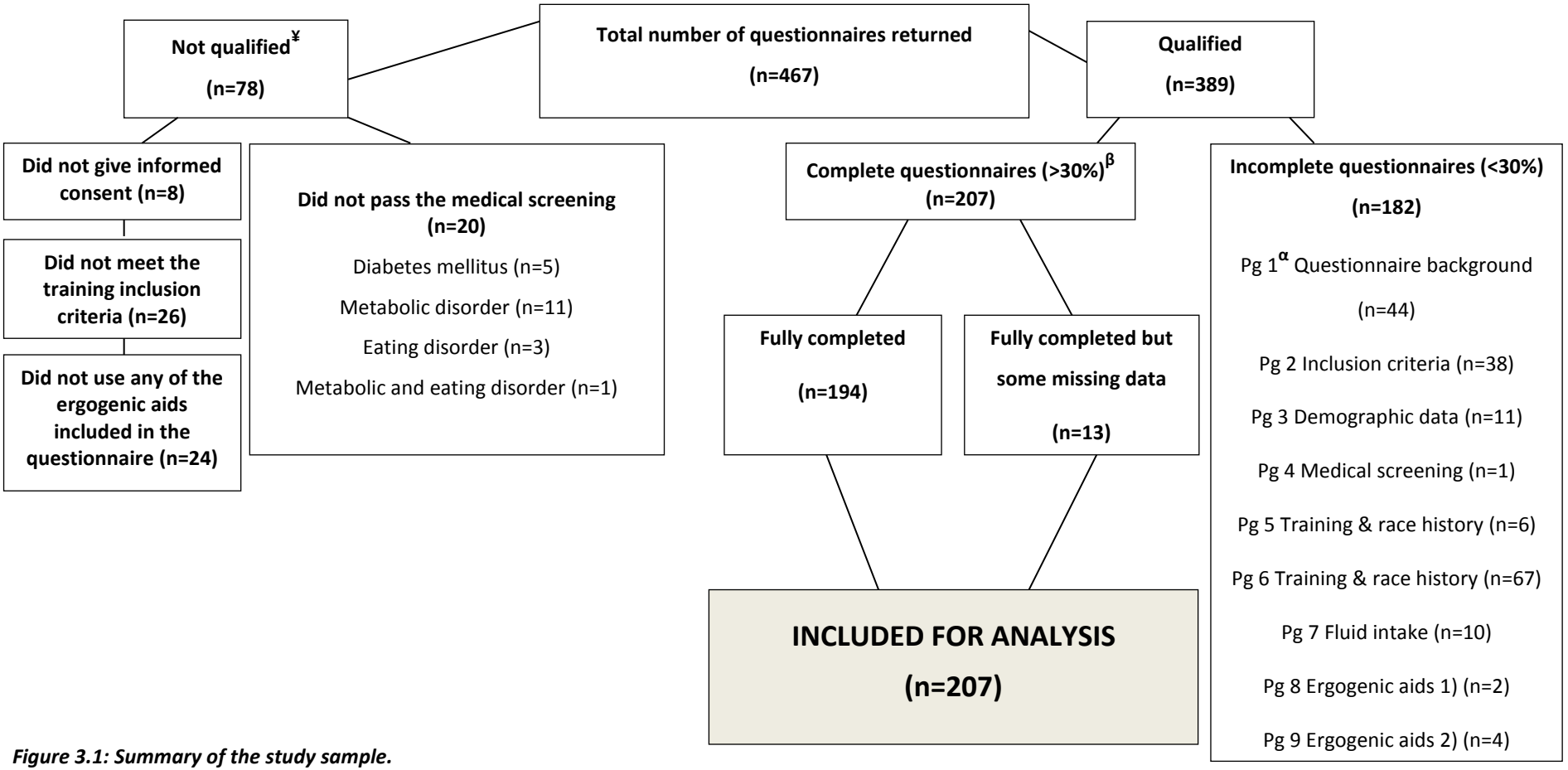

Figure 3.1: Summary of the study sample.

Note:

¥: Not qualified: the online questionnaire terminated due to the nature of the participants' response. They either did not meet the inclusion criteria or were excluded on the basis of medical screening.

β: Complete/ Incomplete questionnaires: if participants' did not complete more than 30% of the questionnaire, it was considered incomplete. By failing to complete more than 30%, participants did not reach Section C: the use of ergogenic aids (page 9 of the online questionnaire).

α: Incomplete questionnaires: the page number indicates the last part of the questionnaire that the participant completed.

3.3.2 Descriptive characteristics

The descriptive characteristics of all participants included in the analysis (n=207) are shown in Table 3.6 and Table 3.7 respectively. There were no significant differences in age, stature, body mass, BMI and level of education between male and female participants.

Table 3.6: Descriptive characteristics of male (n=177) and female (n=30) participants. Data are expressed as mean ± standard deviation (SD).

Descriptive characteristics		
	Male (n=177)	**Female (n=30)**
Age (years)	45.1 ± 11.7	42.1 ± 10.1
Stature (m)	1.8 ± 0.1	1.7 ± 0.1
Body mass (kg)	82.5 ± 11.1	64.1 ± 10.4
BMI	25.6 ± 3.2	23.4 ± 3.2

Table 3.7: Level of education of male (n=177) and female (n=30) participants. Data are expressed as number of responses (n) and percentages (%).

Level of education	**Male (n=177)**	**Female (n=30)**	**Total (n=207)**
PhD	3 (1.5%)	1 (0.5%)	4 (2.0%)
Masters	40 (19.3%)	4 (1.9%)	44 (21.3%)
Honours	35 (16.9%)	5 (2.4%)	40 (19.3%)
Diploma	41 (19.8%)	10 (4.8%)	51 (24.6%)
Undergraduate	40 (19.3%)	5 (2.4%)	45 (21.7%)
Grade 12	17 (8.2%)	5 (2.4%)	22 (10.6%)
Grade 10	1 (0.5%)	0 (0.0%)	1 (0.5%)

Note: Due to rounding off of percentages to one decimal place, the 'Masters' row total is 0.1% out.

3.3.3 Training and competition history

There were no significant differences in participation in competitive cycling or preferred cycling events between male and female participants (Table 3.8).

Table 3.8: Competitive history and preferred cycling event of male (n=177) and female (n=30) participants. Data are expressed as number of responses (n) and percentages (%).

	Male (n=177)	Female (n=30)	Total (n=207)
	Cycle competitively*		
Yes	80 (38.6%)	12 (5.8%)	92 (44.4%)
No	97 (46.9%)	18 (8.7%)	115 (55.6%)
	Preferred cycling event		
Road	107 (51.7%)	20 (9.6%)	127 (61.3%)
Mountain biking	69 (33.3%)	9 (4.4%)	78 (37.7%)
Time trial	1 (0.5%)	1 (0.5%)	2 (1.0%)

There were no significant differences in average weekly mileage ($km.wk^{-1}$) or the number of times participants cycled per week between males and females. The majority of participants cycled four times a week, averaging 80 $km.wk^{-}1$ to 120 $km.wk^{-1}$. Please refer to Appendix VI for weekly training data tables.

3.3.3.1 Performance levels

De Pauw et al[34] recently developed a performance classification system for cyclists based on physiological parameters and training status. As physiological parameters were not assessed in this study, a modified version of De Pauw et al[34] classification system (**Table 3.**9), was used to evaluate the performance level of the participants in this study (Appendix VI).

* Competitive cycling was defined according to the following race times; (i) Cape Argus Pick 'n Pay Cycle Tour (109 km): male-sub 3h15m, female-sub 3h30m, (ii) Momentum 94.7 Cycle Challenge (94.7 km): male-sub 2h45m, female- sub 3h00m, and/or (iii) Amashova Durban Classic (106 km): male-sub 3h00m, female- sub 3h15.

Table 3.9: Classification of participant groups according to performance level (adapted from De Pauw, 2013[34]).

	PL 1	**PL 2**	**PL 3**	**PL 4**	**PL 5**
Term used	Untrained	Healthy/ Physically active	Trained	Highly trained/ Competitive	Professional
Km.wk^{-1}	-	<60 km	60 to 290 km	>250 km	>500 km
Number of times cycle per week	-	-	≥3	>3	>5

Note: "-": not assessed; PL: performance level.

If performance level was assessed according to average weekly mileage only (Appendix VI), none of the participants fell into performance levels one and two. Eighty-eight percent (80.3%, n=183) of participants were classified at performance level three (trained cyclists); 12.2% (n=25) at performance level four (highly trained cyclists); and 0.5% (n=1) at performance level five (professional cyclists).

If performance level was assessed according to the average number of times participants cycled per week only (Appendix VI), 21.8% (n=45) of participants who cycled only once or twice a week were not classified according to De Pauw et al[34], or can be predicted to be classified at performance level one or two. Twenty percent (20.3%, n=42) were classified at performance level three (trained cyclists); 46.3% (n=96) at performance level four (highly trained cyclists); and 11.6% (n=24) at performance level five (professional cyclists).

Considering the two training parameters and where the majority of the participants were placed, average weekly mileage categorised the participants of this study as trained cyclists whereas average weekly frequency of training, categorised the participants as highly trained cyclists. The participants of this study can therefore be classified as ranging between trained and highly trained.

There were no significant differences in the number of recovery days for both types of competitive events between males and females (Table 3.10 and Table 3.11). The majority of the participants had two to three days recovery after a single day race (58.0%, n=120) and multi-stage race (16.4%, n=34) respectively.

Table 3.10: Average number of recovery days of male (n=177) and female (n=30) participants after a single day event (80 km to100 km). Data are expressed as number of responses (n) and percentages (%).

Number of recovery days	**Male (n=177)**	**Female (n=30)**	**Total (n=207)**
1 day	33 (15.9%)	7 (3.4%)	40 (19.3%)
2-3 days	101 (48.8%)	19 (9.2%)	120 (58.0%)
4-5 days	21 (10.1%)	3 (1.5%)	24 (11.6%)
6-7 days	10 (4.8%)	1 (0.5%)	11 (5.3%)
8-10 days	6 (2.9%)	0 (0.0%)	6 (2.9%)
>11 days	6 (2.9%)	0 (0.0%)	6 (2.9%)

Table 3.11: Average number of recovery days of males (n=177) and females (n=30) participants after a multi-stage event. Data are expressed as number of responses (n) and percentages (%).

Number of recovery days	**Male (n=177)**	**Female (n=30)**	**Total (n=207)**
1 day	7 (3.4%)	1 (0.5%)	8 (3.9%)
2-3 days	29 (14.0%)	5 (2.4%)	34 (16.4%)
4-5 days	25 (12.1%)	7 (3.4%)	32 (15.5%)
6-7 days	17 (8.2%)	2 (1.0%)	19 (9.2%)
8-10 days	5 (2.4%)	0 (0.0%)	5 (2.4%)
11-12 days	5 (2.4%)	0 (0.0%)	5 (2.4%)
13-14 days	2 (1.0%)	0 (0.0%)	2 (1.0%)
>15 days	3 (1.5%)	0 (0.0%)	3 (1.5%)
N/A	84 (40.5%)	15 (7.2%)	99 (47.7%)

3.3.4 Type of ergogenic aids used

All ergogenic aids were categorised into three groups for the presentation of the results and discussion section of this dissertation. The three groups included nutritional ergogenic aids (sports drinks/gels, CHO, PRO, amino acids, creatine, and electrolytes); pharmacological ergogenic aids (caffeine, Vitamin B*, NSAIDs, and analgesics); and illegal/banned ergogenic aids (anabolic steroids, HGH, and cortisone) [11]. The ergogenic aid listed as "*other*" (n=15) was excluded from further analysis, as participants had to self-report what "*other*" included, which made it difficult to categorise.

The ergogenic aids used by participants are shown in Figure 3.2. Nutritional ergogenic aids were used by 42.0%; pharmacological ergogenic aids by 23.4%, and illegal/banned ergogenic aids by 0.8% of participants. The highest self-reported ergogenic aid used within each of the groups (nutritional, pharmacological, and illegal/banned) were sports drinks/gels, caffeine and cortisone, and HGH respectively.

*The researcher is aware that Vitamin B can be classified as either a nutritional or pharmacological ergogenic aid. For the purpose of this dissertation it was chosen to be classified as a pharmacological ergogenic aid [11].

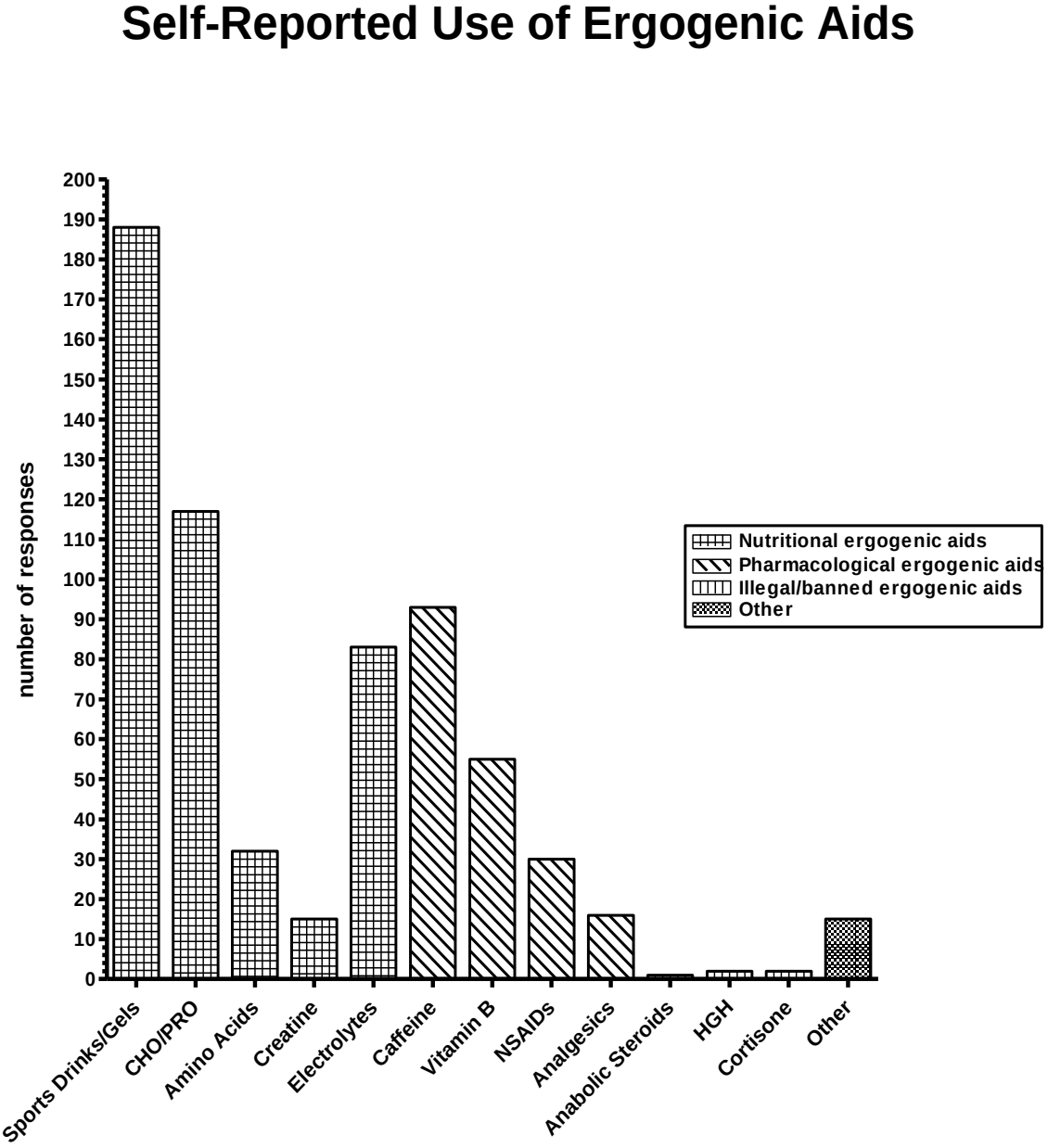

Figure 3.2: Self-reported use of ergogenic aids.

There were no significant differences in the use of ergogenic aids between males and females (Table 3.12). Four participants (all males) used illegal/banned ergogenic aids. They included anabolic steroids, HGH and cortisone. Participants in this study did not use blood transfusions and EPO. The average number of ergogenic aids used by participants in this study was 3.1 (649 total instances/207 total sample size) [187]. Among all the ergogenic aids, sports drinks/gels had the highest reported use (90.8%, n=188), followed by CHO and PRO (56.5%, n=117), caffeine (44.9%, n=93) and electrolytes (40.1%, n=83).

Table 3.12: Use of ergogenic aids in male (n=177) and female (n=30) participants. Data are expressed as number of responses (n) and percentages (%).

Ergogenic aid	Males (n=177)		Females (n=30)		Total number of participants using the aid
	Yes	No	Yes	No	
Sports drinks/gels	163 (78.7%)	14 (6.8%)	25 (12.1%)	5 (2.4%)	188 (90.8%)
Nutritional (CHO and PRO)	101 (48.8%)	76 (36.7%)	16 (7.7%)	14 (6.8%)	117 (56.5%)
Amino acids	30 (14.5%)	147 (71.0%)	2 (1.0%)	28 (13.5%)	32 (15.5%)
Creatine	15 (7.3%)	162 (78.2%)	0 (0.0%)	30 (14.5%)	15 (7.3%)
Electrolytes	70 (33.8%)	107 (51.7%)	13 (6.3%)	17 (8.2%)	83 (40.1%)
Caffeine	81 (39.1%)	96 (46.4%)	12 (5.8%)	18 (8.7%)	93 (44.9%)
Vitamin B	45 (21.7%)	132 (63.8%)	10 (4.8%)	20 (9.7%)	55 (26.6%)
NSAIDs	24 (11.6%)	153 (73.9%)	6 (2.9%)	24 (11.6%)	30 (14.5%)
Analgesics	13 (6.3%)	164 (79.2%)	3 (1.5%)	27 (13.0%)	16 (7.8%)
Anabolic steroids	1 (0.5%)	176 (85.0%)	0 (0.0%)	30 (14.5%)	1 (0.5%)
HGH	2 (1.0%)	175 (84.5%)	0 (0.0%)	30 (14.5%)	2 (1.0%)
Cortisone	2 (1.0%)	175 (84.5%)	0 (0.0%)	30 (14.5%)	2 (1.0%)
Blood transfusions	0 (0.0%)	177 (85.5%)	0 (0.0%)	30 (14.5%)	0 (0.0%)
EPO	0 (0.0%)	177 (85.5%)	0 (0.0%)	30 (14.5%)	0 (0.0%)
Other	14 (6.8%)	163 (78.7%)	1 (0.5%)	29 (14.0%)	15 (7.3%)

3.3.5 Pattern of use of ergogenic aids

3.3.5.1 Nutritional aids

The pattern of use of nutritional ergogenic aids are shown in Figure 3.3, Figure 3.4 and Figure 3.5 respectively. Table 3.13 (page 92) shows the percentage distribution of when all the ergogenic aids were reportedly used. The majority of the participants used sports drinks/gels (48.7%, n=91), CHO (34.9%, n=38) and electrolytes (30.1%, n=25) before/during training and competition respectively. The majority of participants used PRO (28.6%, n=2) equally before training and competition, after training and after training and competition. Amino acids (28.1%, n=9) and creatine (33.3%, n=5) were both used more frequently by participants before training and competition.

Pattern of Use: Sports Drinks/Gels & CHO

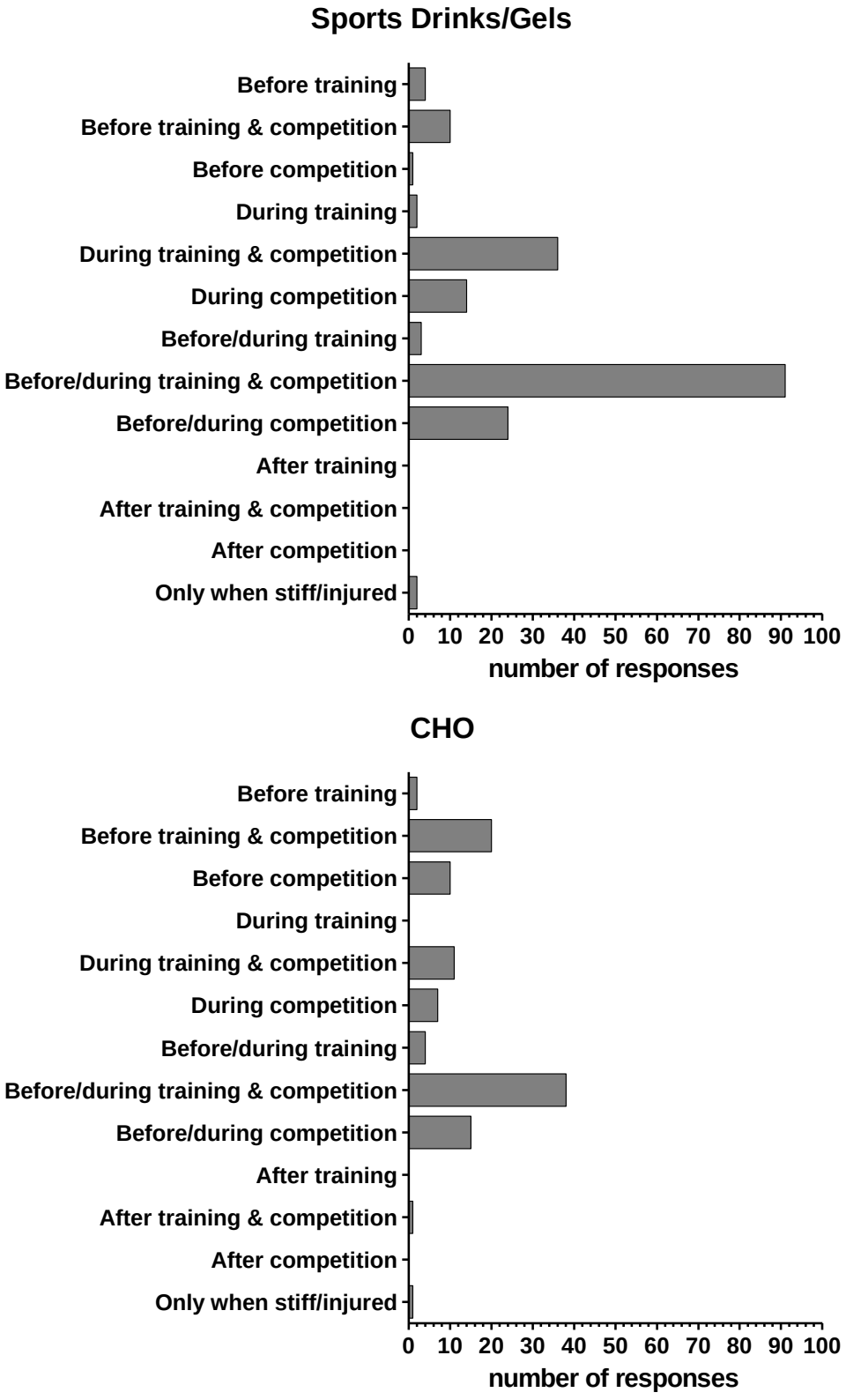

Figure 3.3: Summary of the pattern of use of sports drinks/gels and CHO.

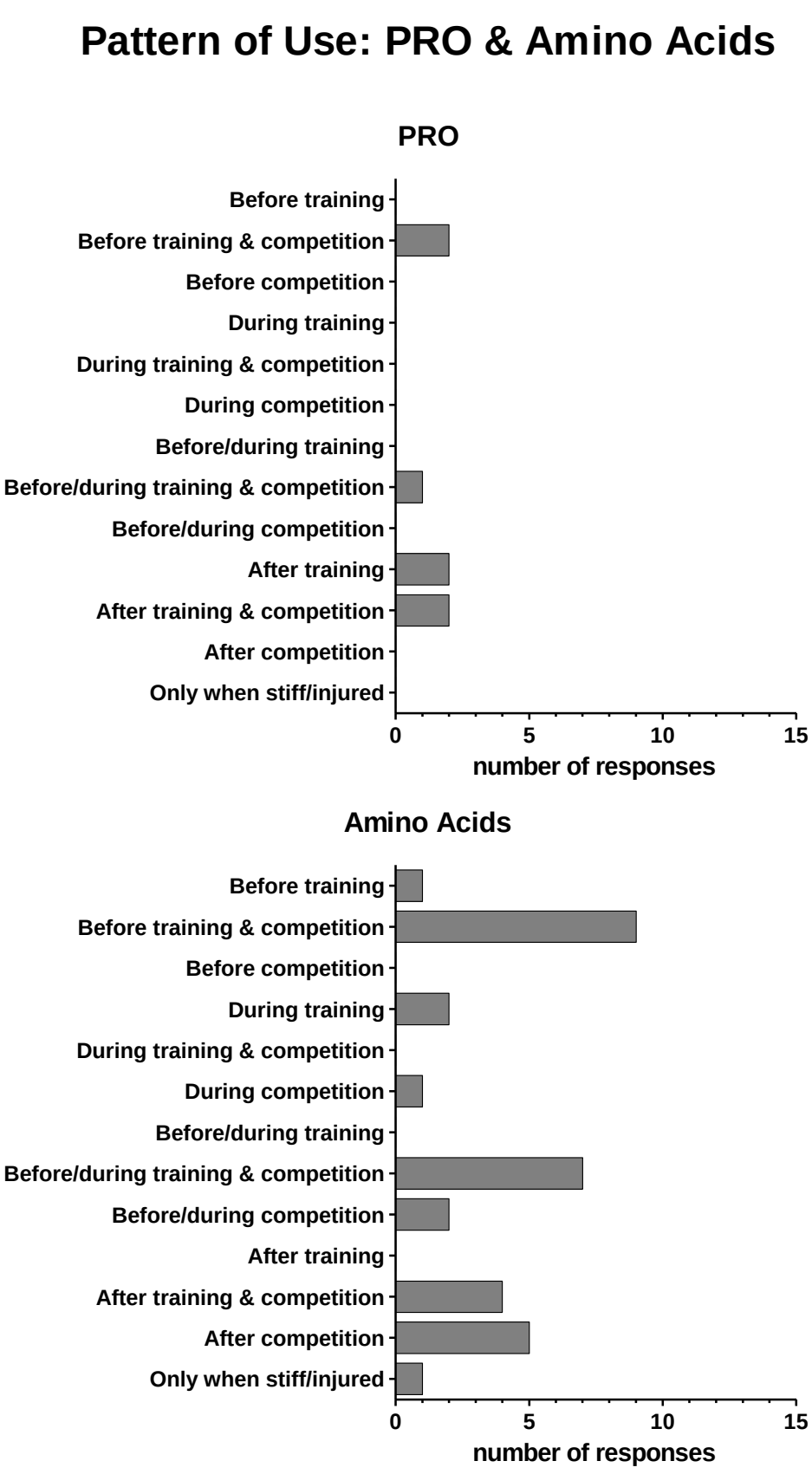

Figure 3.4: Summary of the pattern of use of PRO and amino acids.

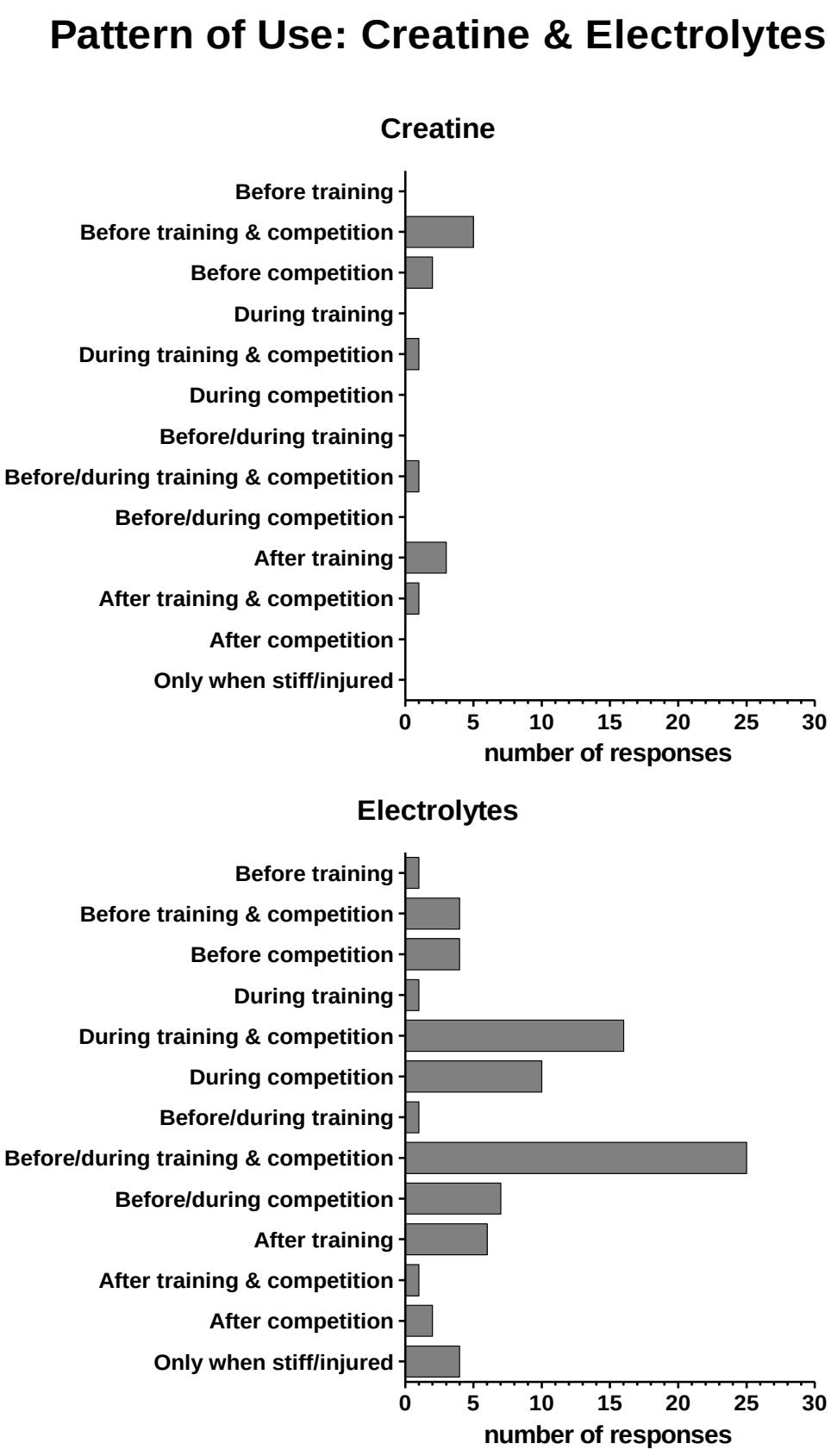

Figure 3.5: Summary of the pattern of use of creatine and electrolytes.

3.3.5.2 Pharmacological aids

Figure 3.6 and

Figure ***3.7*** show when pharmacological ergogenic aids were used by participants. The majority of participants used caffeine (40.9%, n=38) and Vitamin B (45.5%, n=25) before training and competition. Non-steroidal anti-inflammatories (66.7%, n=20) and analgesics (43.8%, n=7) were mostly used by participants only when they were stiff and/or injured.

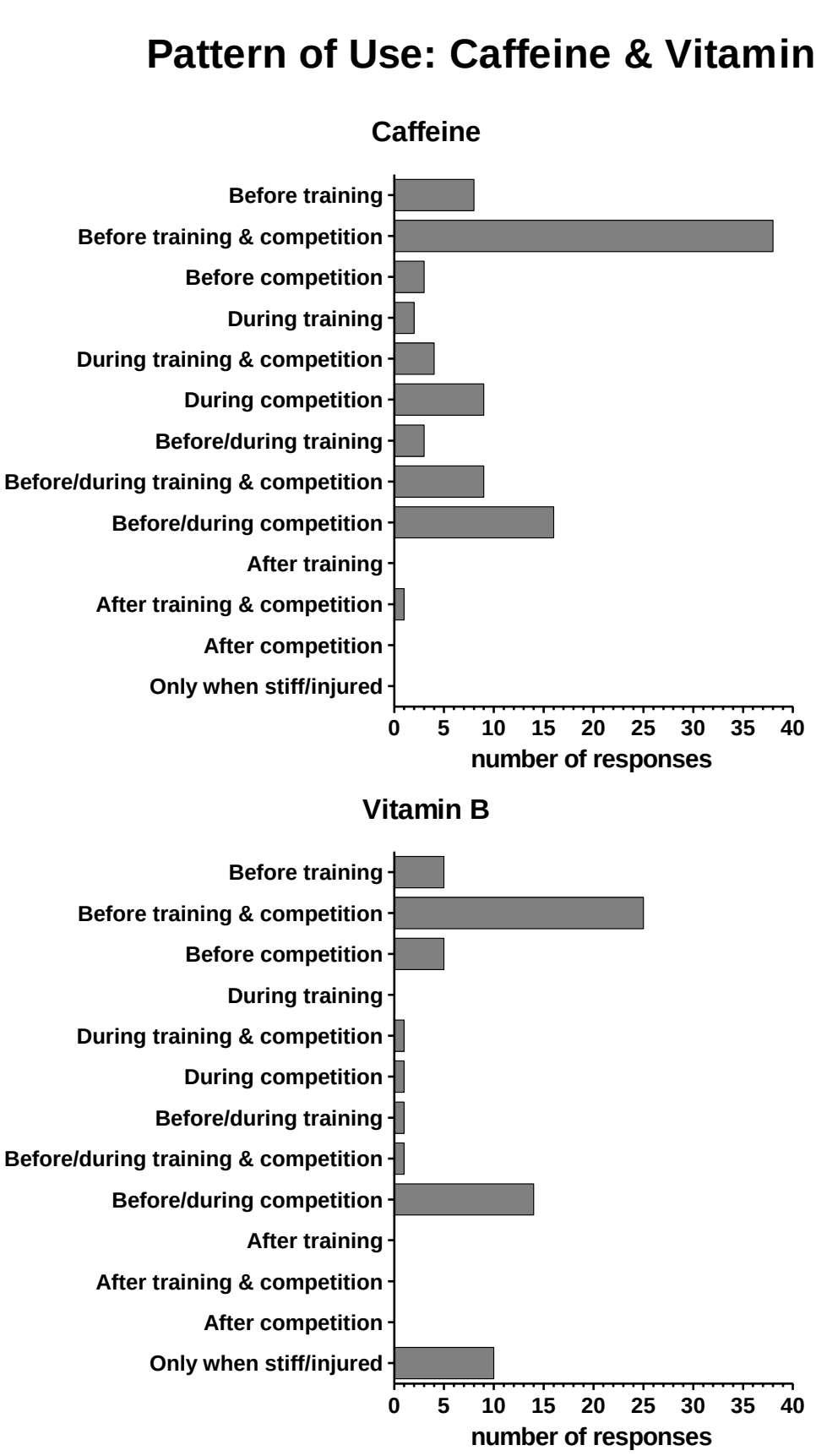

Figure 3.6: Summary of the pattern of use of caffeine and Vitamin B.

Pattern of Use: NSAIDs & Analgesics

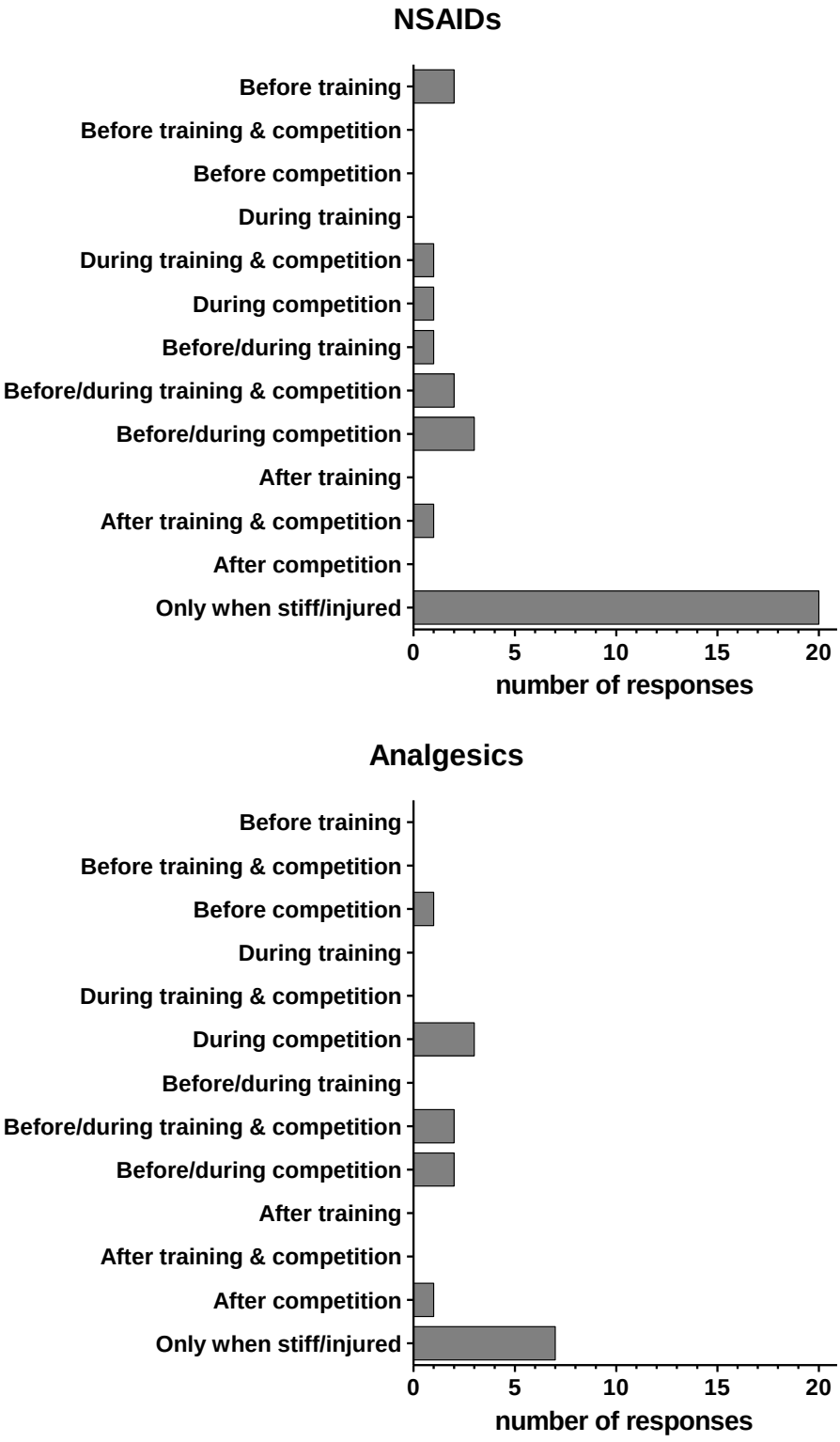

Figure 3.7: Summary of the pattern of use of NSAIDs and analgesics.

3.3.5.3 Illegal/banned aids

Figure 3.8 shows when the illegal/banned ergogenic aids were used. Anabolic steroids were reported to be used by one participant before/during competition. Human growth hormone (n=1) was reportedly used before training and competition, while cortisone (n=2) was only used when participants were stiff and/or injured.

Pattern of Use: Illegal/Banned Ergogenic Aids

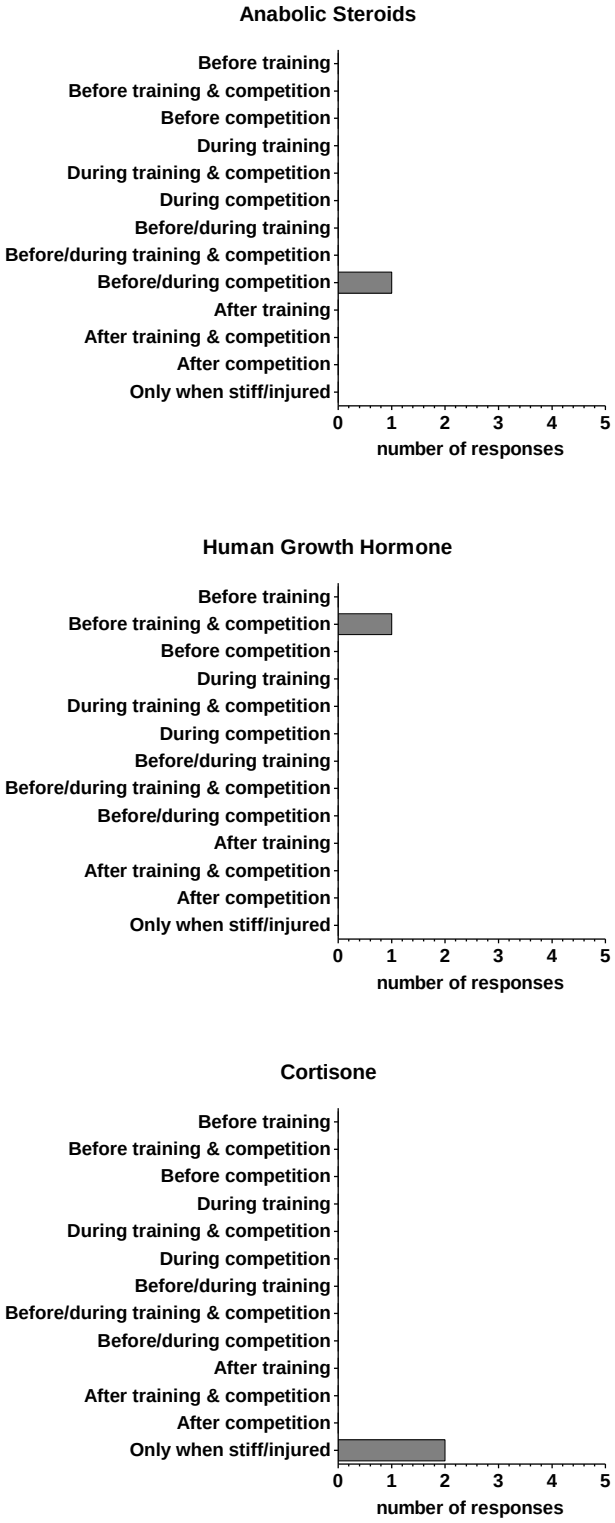

Figure 3.8: Summary of the pattern of use of anabolic steroids, HGH and cortisone.

Table 3.13 summarise the pattern of use of all categories of ergogenic aids.

Table 3.13: Summary of the self-reported pattern of use of ergogenic aids by cyclists. Data are expressed as percentages (%).

	Sports drinks/gels	CHO	PRO	Amino Acids	Creatine	Electrolyte	Caffeine	Vitamin B	NSAIDs	Analgesics	Anabolic steroids	HGH	Cortisone
Before training	2.1%	1.8%	0.0%	3.1%	0.0%	1.2%	8.6%	9.1%	6.7%	0.0%	0.0%	0.0%	0.0%
Before training & competition	5.3%	18.3%	28.6%	28.1%	33.3%	4.8%	40.9%	45.5%	0.0%	0.0%	0.0%	100.0 %	0.0%
Before competition	0.5%	9.2%	0.0%	0.0%	13.3%	4.8%	3.2%	9.1%	0.0%	6.3%	0.0%	0.0%	0.0%
During training	1.1%	0.0%	0.0%	6.3%	0.0%	1.2%	2.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
During training & competition	19.3%	10.1%	0.0%	0.0%	6.7%	19.3%	4.3%	1.8%	3.3%	0.0%	0.0%	0.0%	0.0%
During competition	7.5%	6.4%	0.0%	3.1%	0.0%	12.0%	9.7%	1.8%	3.3%	18.8%	0.0%	0.0%	0.0%
Before & during training	1.6%	3.7%	0.0%	0.0%	0.0%	1.2%	3.2%	1.8%	3.3%	0.0%	0.0%	0.0%	0.0%
Before & during training & competition	48.7%	34.9%	14.2%	21.9%	6.7%	30.1%	9.7%	1.8%	6.7%	12.5%	0.0%	0.0%	0.0%

Note: The selection of timing was chosen from individual and specific options as listed above.

Table 3.13 (continued): Summary of the self-reported pattern of use of ergogenic aids by cyclists. Data are expressed as percentages (%).

	Sports drinks/gels	CHO	PRO	Amino Acids	Creatine	Electrolyte	Caffeine	Vitamin B	NSAIDs	Analgesics	Anabolic steroids	HGH	Cortisone
Before & during competition	12.8%	13.8%	0.0%	6.3%	0.0%	8.4%	17.2%	25.5%	10.0%	12.5%	100.0 %	0.0%	0.0%
After training	0.0%	0.0%	28.6%	0.0%	20.0%	7.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
After training & competition	0.0%	0.9%	28.6%	12.5%	6.7%	1.2%	1.1%	0.0%	3.3%	0.0%	0.0%	0.0%	0.0%
After competition	0.0%	0.0%	0.0%	15.6%	0.0%	2.4%	0.0%	0.0%	0.0%	6.3%	0.0%	0.0%	0.0%
Only if stiff/injured	1.1%	0.9%	0.0%	3.1%	0.0%	4.8%	0.0%	18.2%	66.7%	43.8%	0.0%	0.0%	100.0 %

Note: The selection of timing was chosen from individual and specific options as listed above.

3.3.6 Details of the ergogenic aids used

3.3.6.1 Nutritional aids

Table 3.14 and Table 3.15 show detailed information regarding the nutritional ergogenic aids that were used by participants. Sports drinks (61.3%, n=114) were used more regularly than gels (6.4%, n=12). Refined (35.2%, n=75) and dense (35.7%, n=76) CHO were mostly consumed. Of the refined and dense CHO consumed, sports drinks (37.4%, n=101) and pasta/potato (28.6%, n=75) were the most popular. Carbohydrates (60.2%, n=59) were mostly ingested within 30 minutes of finishing training or a competition. Liquid PRO (40.0%, n=6) was the most popular form of PRO used. Of the liquid and lean PRO, milk (44.5%, n=4) and eggs (35.7%, n=5) were consumed the most. Protein (57.1%, n=4) was mostly ingested within 30 minutes of finishing training or a competition. The majority of participants (58.0%, n=18) used both whey and BCAA. Electrolytes (59.5%, n=47) were mostly ingested within 30 minutes of finishing training or a competition.

Table 3.14: Details regarding the self-reported use of sports drinks/gels and CHO. Data are expressed as number of responses (n) and percentages (%).

Which product do you use more frequently: Sports drinks or gels?	**Number of responses (n)**
Sports drinks	114 (61.3%)
Gels	12 (6.4%)
Both	60 (32.3%)
How soon after training or competition do you ingest carbohydrates?	
Within 30 minutes of finishing	59 (60.2%)
Within two to four hours of finishing	17 (17.3%)
>six hours of finishing	1 (1.0%)
Within no specific time period	3 (3.1%)
I do not ingest carbohydrates after training or competition	18 (18.4%)
What form of carbohydrate do you ingest?	
Refined	75 (35.2%)
Dense	76 (35.7%)
Supplement	56 (26.3%)
Other	6 (2.8%)
What type of refined carbohydrate do you ingest?	
Sports drinks	101 (37.4%)
Soft drinks	30 (11.1%)
Sweets	25 (9.3%)
Gels	50 (18.5%)
Sports bars	61 (22.6%)
Other	3 (1.1%)
What type of dense carbohydrate do you ingest?	
Bread	63 (24.1%)
Cereal	53 (20.2%)
Pasta/potato	75 (28.6%)
Rice	31 (11.8%)
Fruit	37 (14.1%)
Other	3 (1.2%)

Table 3.15: Details regarding the self-reported use of PRO, amino acids and electrolytes. Data are expressed as number of responses (n) and percentages (%).

How soon after training or competition do you ingest protein?	
Within 30 minutes of finishing	4 (57.1%)
Within two to four hours of finishing	1 (14.3%)
>six hours of finishing	1 (14.3%)
Within no specific time period	1 (14.3%)
I do not ingest protein after training or competition	0 (0.0%)
What form of protein do you ingest?	
Liquid	6 (40.0%)
Lean	5 (33.3%)
Powder	3 (20.0%)
Other	1 (6.7%)
What type of liquid protein do you ingest?	
Milk	4 (44.5%)
Liquid meal replacement	2 (22.2%)
Body building protein powder	3 (33.3%)
Skim milk powder	0 (0.0%)
Other	0 (0.0%)
What type of lean protein do you ingest?	
Skinless chicken	4 (28.6%)
Fish	3 (21.4%)
Eggs	5 (35.7%)
Low fat yogurt	2 (14.3%)
Other	0 (0.0%)
Which amino acid product do you use most frequently?	
BCAA	6 (19.4%)
Whey	6 (19.4%)
Both	18 (58.0%)
Other	1 (3.2%)

Table 3.15 (continued): Details regarding the self-reported use of PRO, amino acids and electrolytes. Data are expressed as number of responses (n) and percentages (%).

How soon after training or competition do you ingest electrolytes?	
Within 30 minutes of finishing	47 (59.5%)
Within two to four hours of finishing	12 (15.2%)
>six hours of finishing	0 (0.0%)
Within no specific time period	11 (13.9%)
I do not ingest electrolytes after training or competition	9 (11.4%)

3.3.6.2 Pharmacological aids

Table 3.16 shows detailed information regarding the pharmacological ergogenic aids that were used by participants. Participants mostly consumed caffeine (54.5%, n=67) through coffee. The NSAID and analgesic dosages used were similar. The majority of participants took two tablets per dose (NSAIDs 53.5%, n=15 and analgesics 73.3%, n=11); one dose per day (NSAIDs 40.8%, n=11 and analgesics 53.3%, n=8) for a duration of one day (NSAIDs 39.3%, n=11 and analgesics 60.0%, n=9).

Table 3.16: Details regarding the self-reported use of caffeine, NSAIDs and analgesics. Data are expressed as number of responses (n) and percentages (%).

What form of caffeine do you use?	**Number of responses (n)**
Coffee	67 (54.5%)
Capsules	10 (8.1%)
Red Bull	7 (5.7%)
Chocolate	9 (7.3%)
Other	30 (24.4%)
How do you administer NSAIDs?	
Orally	26 (89.7%)
Intravenously	1 (3.4%)
Both	2 (6.9%)
Number of NSAID tablets taken per dose?	
One	12 (42.9%)
Two	15 (53.5%)
Three	1 (3.6%)
Four	0 (0.0%)
Number of NSAID doses per day?	
One	11 (40.8%)
Two	10 (37.0%)
Three	6 (22.2%)
Four	0 (0.0%)
Numbers of days, NSAIDs are taken for?	
One	11 (39.3%)
Two to three days	10 (35.7%)
One-week	1 (3.6%)
As long as I feel I need too	5 (17.8%)
Five	1 (3.6%)

Table 3.16 (continued): Details regarding the self-reported use of caffeine, NSAIDs and analgesics. Data are expressed as number of responses (n) and percentages (%).

Number of analgesic tablets taken per dose?	
One	2 (13.3%)
Two	11 (73.3%)
Three	1 (6.7%)
Four	1 (6.7%)
Number of analgesic doses per day?	
One	8 (53.3%)
Two	6 (40.0%)
Three	1 (6.7%)
Four	0 (0.0%)
Numbers of days, analgesics are taken for?	
One	9 (60.0%)
Two to three days	3 (20.0%)
One-week	0 (0.0%)
As long as I feel I need too	3 (20.0%)

3.3.6.3 Illegal/banned aids

Table 3.17 shows detailed information regarding the illegal/banned ergogenic aids that were used by participants. Human growth hormone and cortisone were both reported to be administered intravenously. Participants used medical support personnel to help administer both HGH and cortisone. General practitioners and team mates were also reportedly used.

Table 3.17: Details regarding the self-reported use of HGH and cortisone. Data are expressed as number of responses (n) and percentages (%).

How do you administer human growth hormone?	**Number of responses (n)**
Orally	0 (0.0%)
Intravenously	2 (100.0%)
Do you use human growth hormone for therapeutic purposes or performance enhancing purposes?	
Therapeutic	1 (50.0%)
Performance	1 (50.0%)
Do you have help administering human growth hormone?	
General practitioner	0 (0.0%)
Physiotherapist	0 (0.0%)
Medical support personal	1 (50.0%)
Team mate	1 (50.0%)
Other	0 (0.0%)
How do you administer cortisone?	
Orally	0 (0.0%)
Intravenously	2 (100.0%)
Do you use cortisone for therapeutic purposes or performance enhancing purposes?	
Therapeutic	1 (50.0%)
Performance	1 (50.0%)
Do you have help administering cortisone?	
General practitioner	1 (50.0%)
Physiotherapist	0 (0.0%)
Medical support personal	1 (50.0%)
Team mate	0 (0.0%)
Other	0 (0.0%)

3.3.7 Perceived effect of ergogenic aids

3.3.7.1 Nutritional aids

Figure 3.9 and Figure 3.10 show the perceived effect of nutritional ergogenic aids. Table.3.18 summarises participants' perception of effect of ergogenic aids used, expressed as percentages (%). Most participants perceived that sports drinks/gels (81.1%, n=150), CHO and PRO (75.0%, n=6), and electrolytes (60.8%, n=48) increased endurance and time to fatigue. Amino acids (53.3%, n=16) and creatine (53.8%, n=7) were mostly perceived to decrease cellular damage and increase strength and power respectively.

Perception of Effect: Sports Drinks/Gels & CHO/PRO

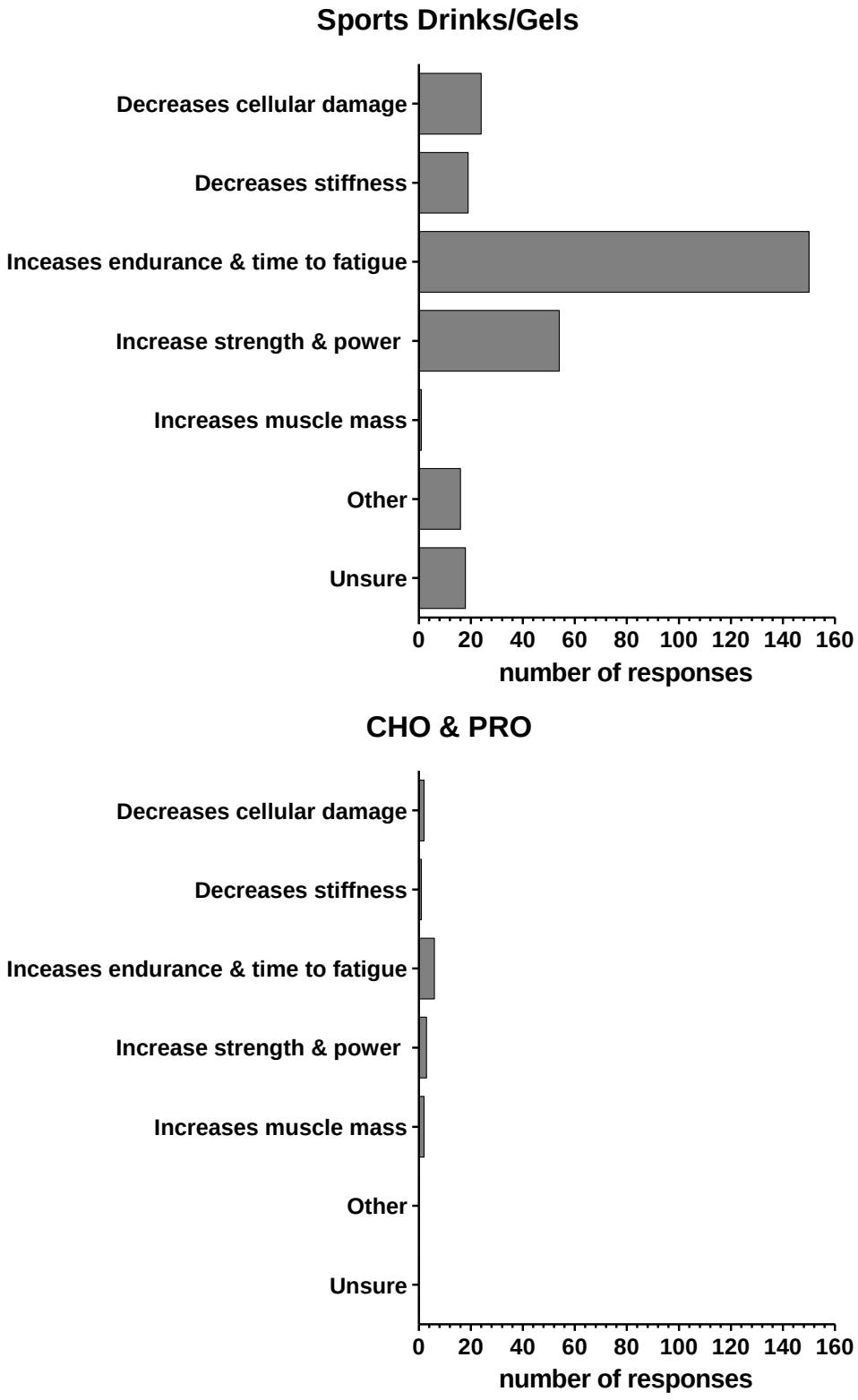

Figure 3.9: Participants' perception of effect of sports drinks/gels and CHO & PRO.

Perception of Effect: Amino Acids, Creatine & Electrolytes

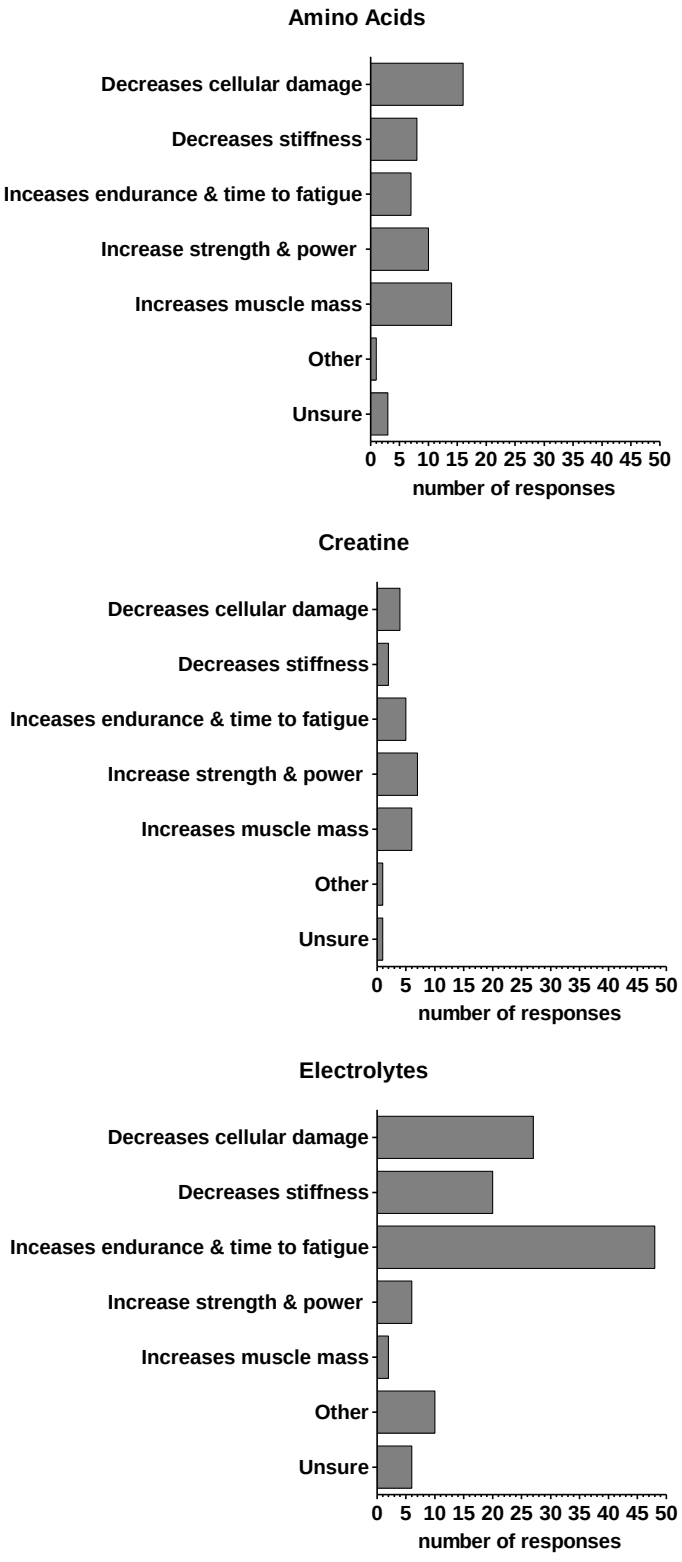

Figure 3.10: Participants' perception of effect of amino acids, creatine and electrolytes.

3.3.6.2 Pharmacological aids

Figure 3.11 and Figure 3.12 show the perceived effect of pharmacological ergogenic aids. Most participants believed that caffeine (50.0%, n=46) and Vitamin B (34.6%, n=18) increased endurance and time to fatigue. Non-steroidal anti-inflammatories (71.4%, n=20) and analgesics (53.3%, n=8) were both commonly perceived to decrease stiffness.

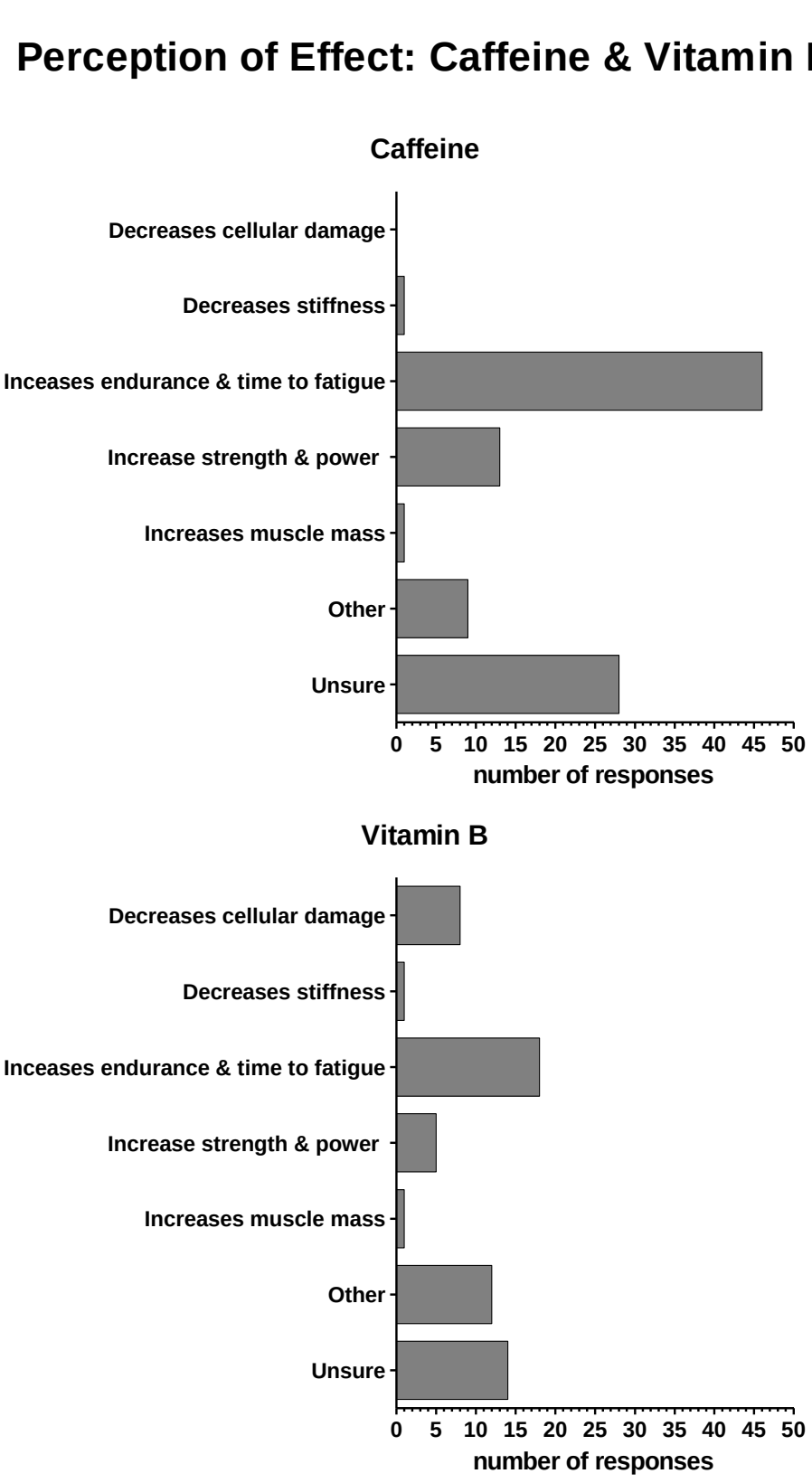

Figure 3.11: Participants' perception of effect of caffeine and Vitamin B.

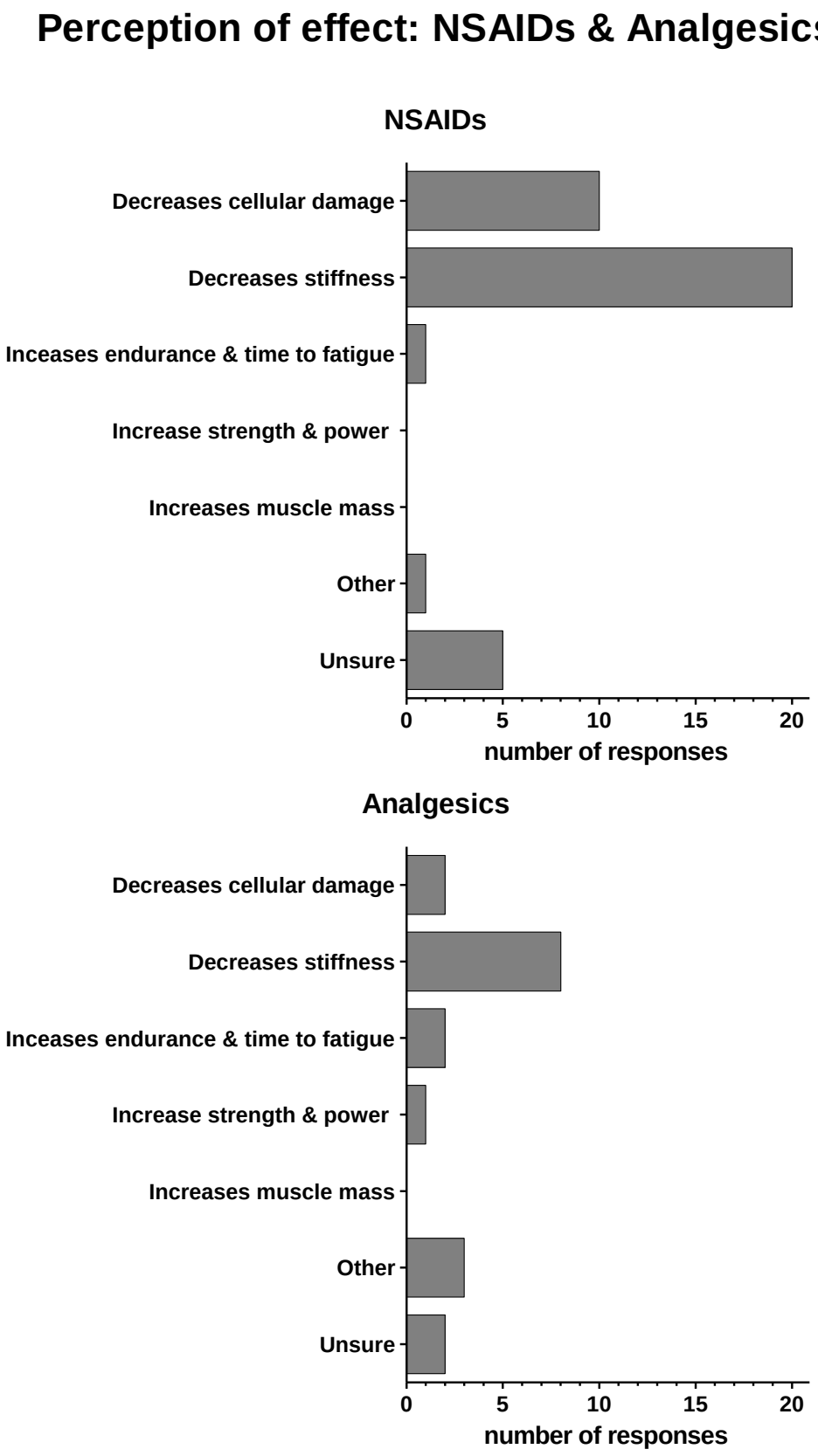

Figure 3.12: Participants' perception of effect of NSAIDs and analgesics.

3.3.6.3 Illegal/banned ergogenic aids

Figure 3.13 shows the perceived effect of illegal/banned ergogenic aids. Anabolic steroids were perceived to increase endurance and time to fatigue as well as increase strength and power. Human growth hormone was perceived to decrease stiffness, however one participant (of two only) was unsure of how it worked. Cortisone was perceived to decrease stiffness and decrease cellular damage.

Perception of Effect: Illegal/Banned Ergogenic Aids

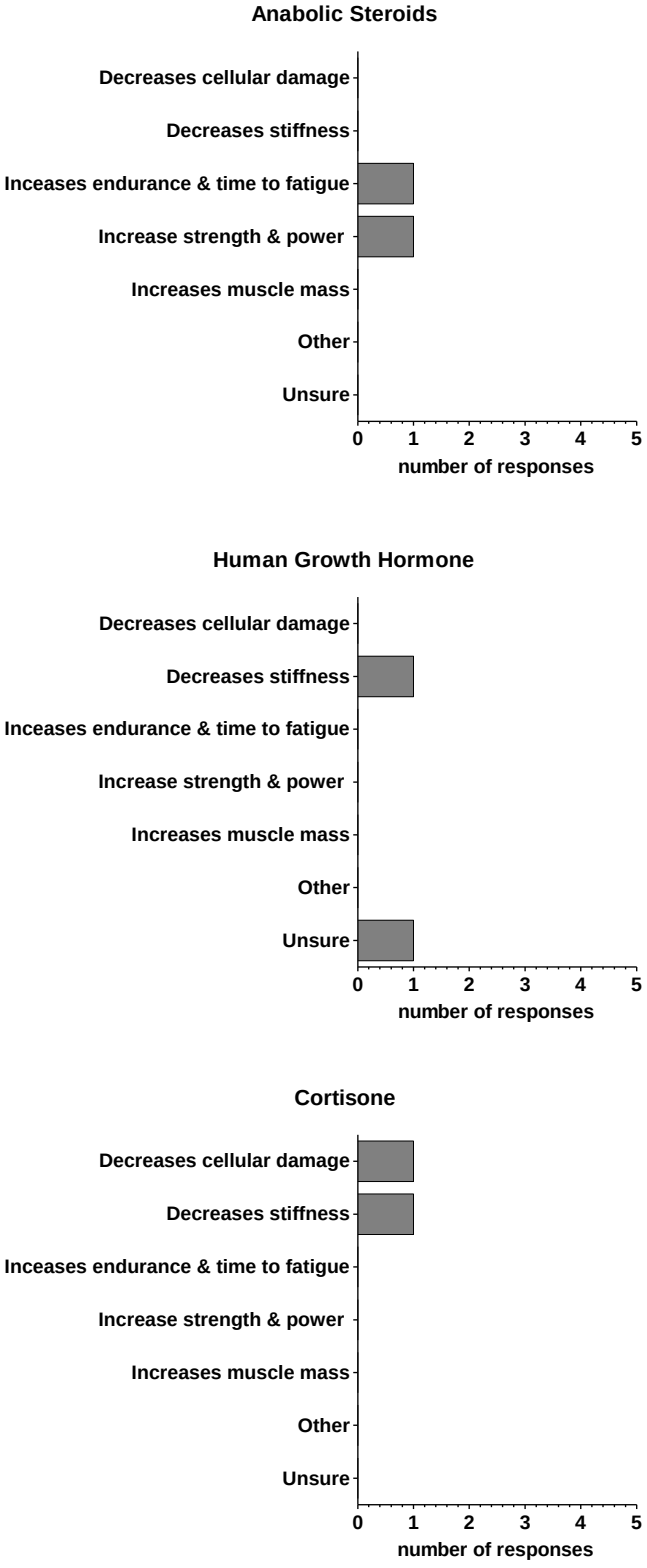

Figure 3.13: Participants' perception of effect anabolic steroids, HGH and cortisone.

Table.3.18 below summarises participants' perception of effect of all categories of ergogenic aids.

Table 3.18: Summary of participants' perception of effect of ergogenic aids. Data expressed as percentages (%).

	Sports drinks/gels	CHO &PRO	Amino Acids	Creatine	Electrolyte	Caffeine	Vitamin B	NSAIDs	Analgesics	Anabolic steroids	HGH	Cortisone
Decrease cellular damage	13.0%	25.0%	51.6%	23.1%	34.2%	0.0%	15.4%	35.7%	13.3%	0.0%	0.0%	50.0%
Decrease stiffness	10.3%	12.5%	25.8%	19.2%	25.3%	1.1%	1.9%	71.4%	53.3%	0.0%	50.0%	50.0%
Increase endurance and time to fatigue	81.1%	75.0%	22.6%	26.9%	60.8%	50.0%	34.6%	3.6%	13.3%	50.0%	0.0%	0.0%
Increase strength and power	29.2%	37.5%	32.3%	15.4%	7.6%	14.1%	9.6%	0.0%	6.7%	50.0%	0.0%	0.0%
Increase muscle mass	0.5%	25.0%	45.2%	7.7%	2.5%	1.1%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%
Other	8.6%	0.0%	3.2%	3.8%	12.7%	9.8%	23.1%	3.6%	20.0%	0.0%	0.0%	0.0%
Unsure	9.7%	0.0%	9.7%	3.8%	7.6%	30.4%	26.9%	17.9%	13.2%	0.0%	50.0%	0.0%

Key: CHO: carbohydrate; PRO: protein.

3.3.7 Participants' perceived effect of ergogenic aids on performance

Figure 3.14 shows the perceived effect of ergogenic aids on performance. Responses were grouped according to whether participants believed that the ergogenic aid improved their performance; and if they had to stop using the ergogenic aids, whether their performance would deteriorate respectively. Responses have been presented as three domains, namely: "*yes/yes*", where participants responded positively to both questions; "*yes/no*", where participants thought that although the aid improved their performance, their performance would not deteriorate if they stopped using the aid; and "*no/no*", where participants responded negatively to both questions.

The majority of participant's (71.0% to 87.5%) using nutritional ergogenic aids where grouped in the "*yes/yes*" domain. Sports drinks/gels (6.5%, n=12), amino acids (12.9%, n=4), creatine (23.1%, n=3) and electrolytes (5.1%, n=4) had participants in the "*yes/no*" domain. Sports drinks/gels (8.1%, n=15), CHO and PRO (12.5%, n=1), amino acids (16.1%, n=5) and electrolytes (19.0%, n=15) had participants in the "*no/no*" domain.

Of the pharmacological ergogenic aids caffeine (34.8%, n=32), Vitamin B (34.6%, n=18), NSAIDs (39.3%, n=11) and analgesics (60.0%, n=9) had participants in the "*yes/yes*" domain. Caffeine (37.0%, n=34) and Vitamin B (36.5%, n=19) had more participants in the "*yes/no*" domain. Non-steroidal anti-inflammatories (57.1%, n=16) had the majority of participants in the "*no/no*" domain.

The one participant who reported using anabolic steroids was grouped in the "*yes/yes*" domain. The participants who used HGH (n=2) and cortisone (n=2) both had one participant grouped in the "*yes/no*" domain and one participant in the "*no/no*" domain respectively.

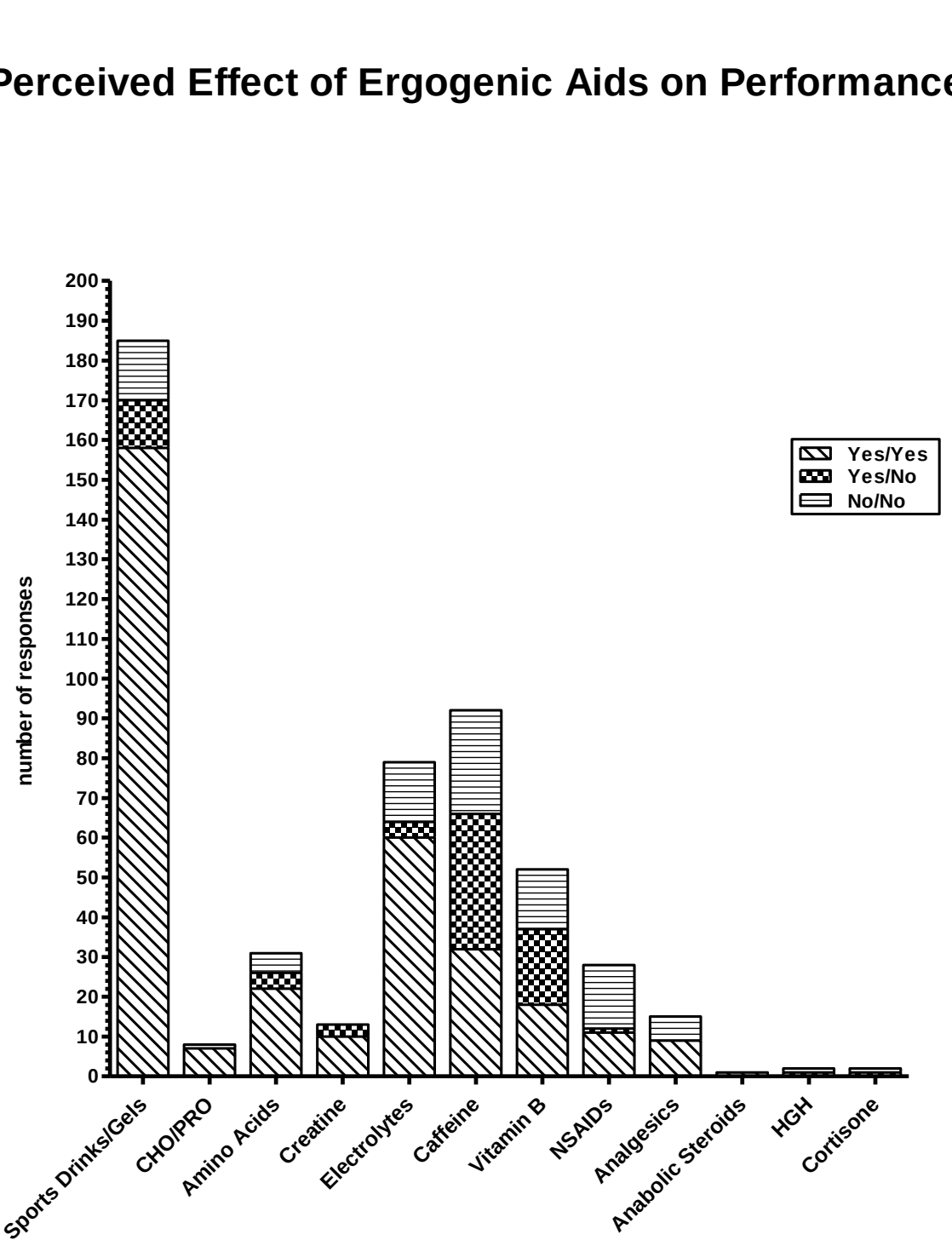

Figure 3.14: Participants' perceived effect of ergogenic aids on performance.

3.3.8 Sources of information influencing the use of specific ergogenic aids

Less than 12% of participants sought information from research articles as their primary source of information. Participants using ergogenic aids mainly obtained information from "*questionable*" resources, such as self-experimentation (51.7%), fellow cyclists (13.7%), books/magazines (8.6%), coaches/trainers (7.0%), the internet (5.5%), and adverts (2.3%) as their primary source [(59)].

3.3.8.1 Nutritional aids

Participant's primary source of information influencing the use of all nutritional ergogenic aids (sports drinks/gels 50.5%, n=92; CHO and PRO 85.7%, n=6; amino acids 30.0%, n=9; creatine 45.5%, n=5; and electrolytes 54.5%, n=42) was self-experimentation (Figure 3.15 and Figure 3.16). Fellow cyclists were the second most influential source for sports drinks/gels (25.9%, n=43), CHO and PRO (57.1%, n=4) and electrolytes (33.8%, n=25). The third most influential sources of information across all the nutritional ergogenic aids (n=5) were adverts (n=3), books/magazines (n=2) and research articles (n=1).

Source of Information: Sports Drinks/Gels & CHO/PRO

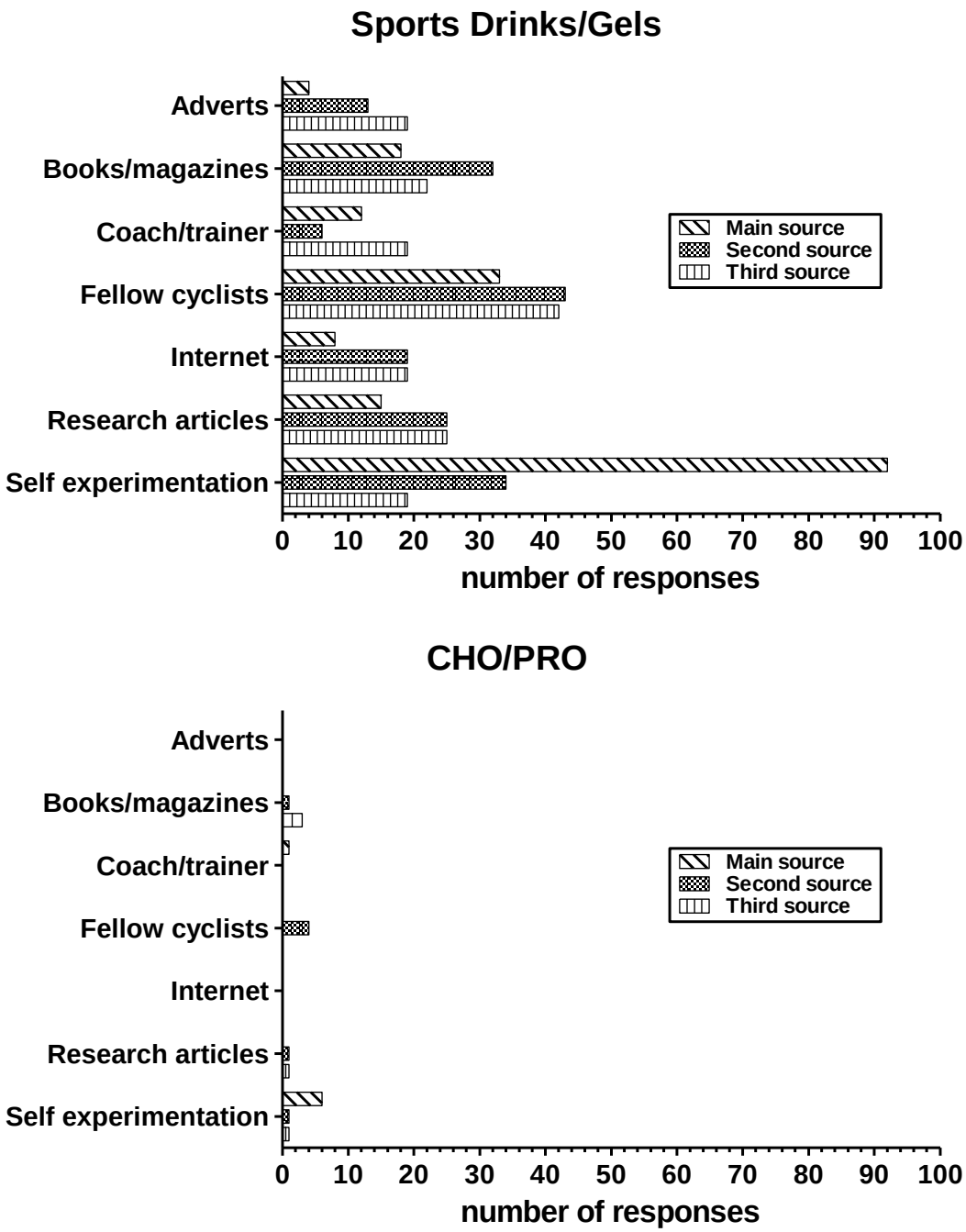

Figure 3.15: Sources of information influencing the use of sports drinks/gels and CHO & PRO.

Source of Information: Amino Acids, Creatine & Electrolytes

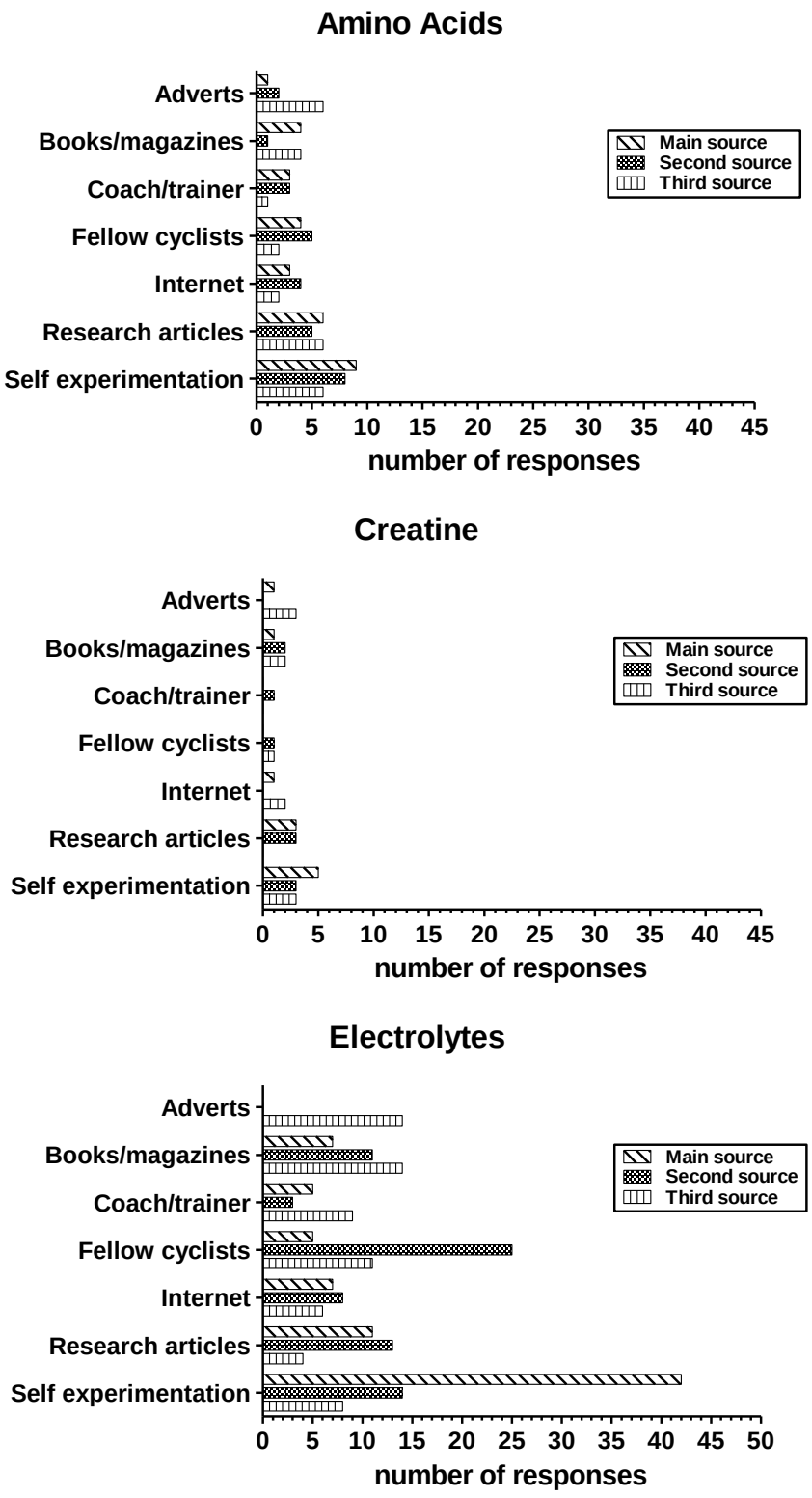

Figure 3.16: Sources of information influencing the use of amino acids, creatine and electrolytes.

3.3.8.2 Pharmacological aids

Participant's primary source of information influencing the use of all pharmacological ergogenic aids (caffeine 46.7%, n=42; Vitamin B 42.6%, n=20; NSAIDs 76.0%, n=19; and analgesics 80.0%, n=12) was self-experimentation (Figure 3.17 and Figure 3.18). The second most influential source for caffeine (25.9%, n=21) was fellow cyclists, whereas for NSAIDs (30.4%, n=7) and analgesics (36.4%, n=4) it was research articles. The third most influential sources of information across all the pharmacological ergogenic aids (n=4) were fellow cyclists (n=3) and books/magazines (n=1).

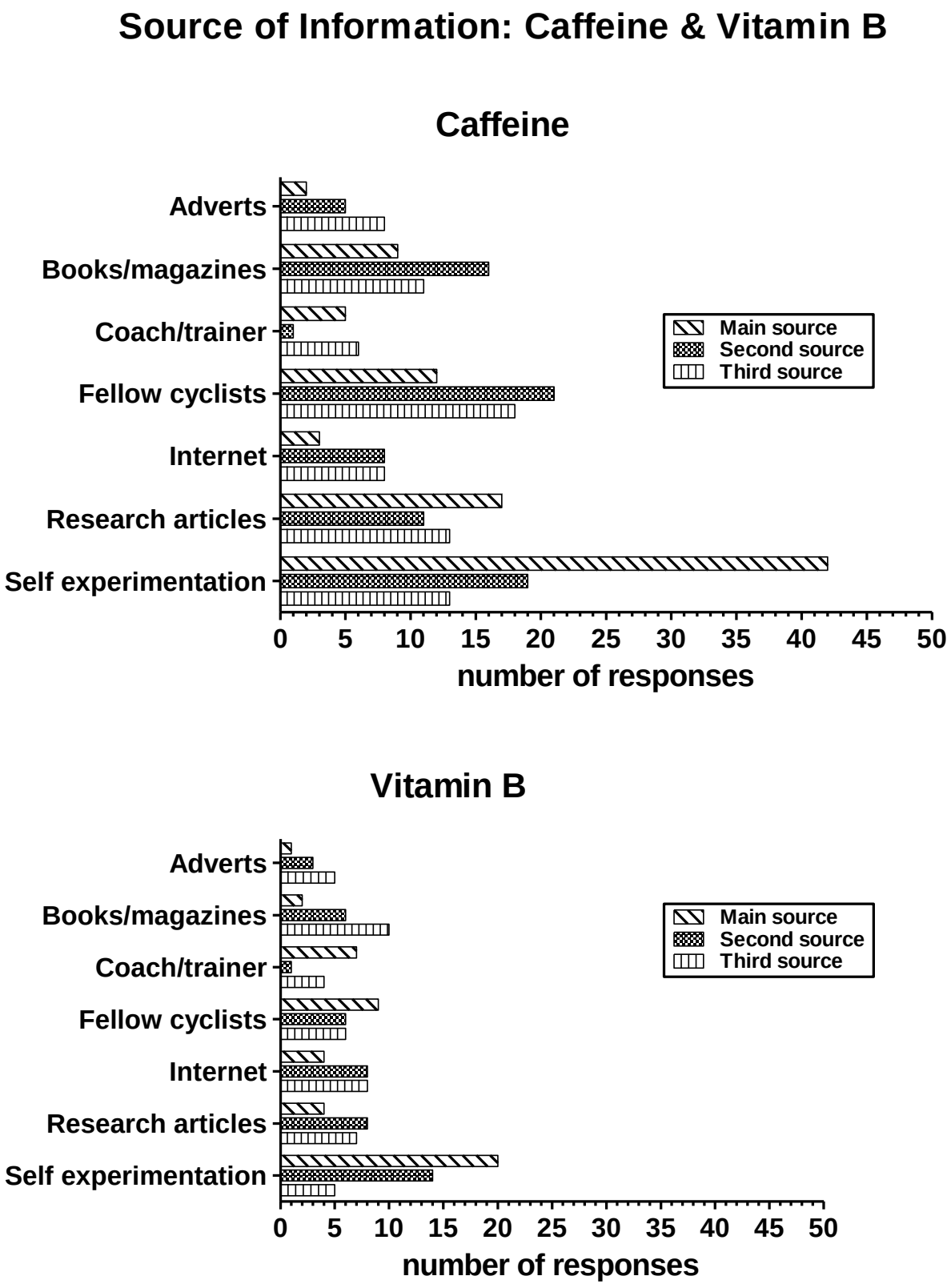

Figure 3.17: Sources of information influencing the use of caffeine and Vitamin B.

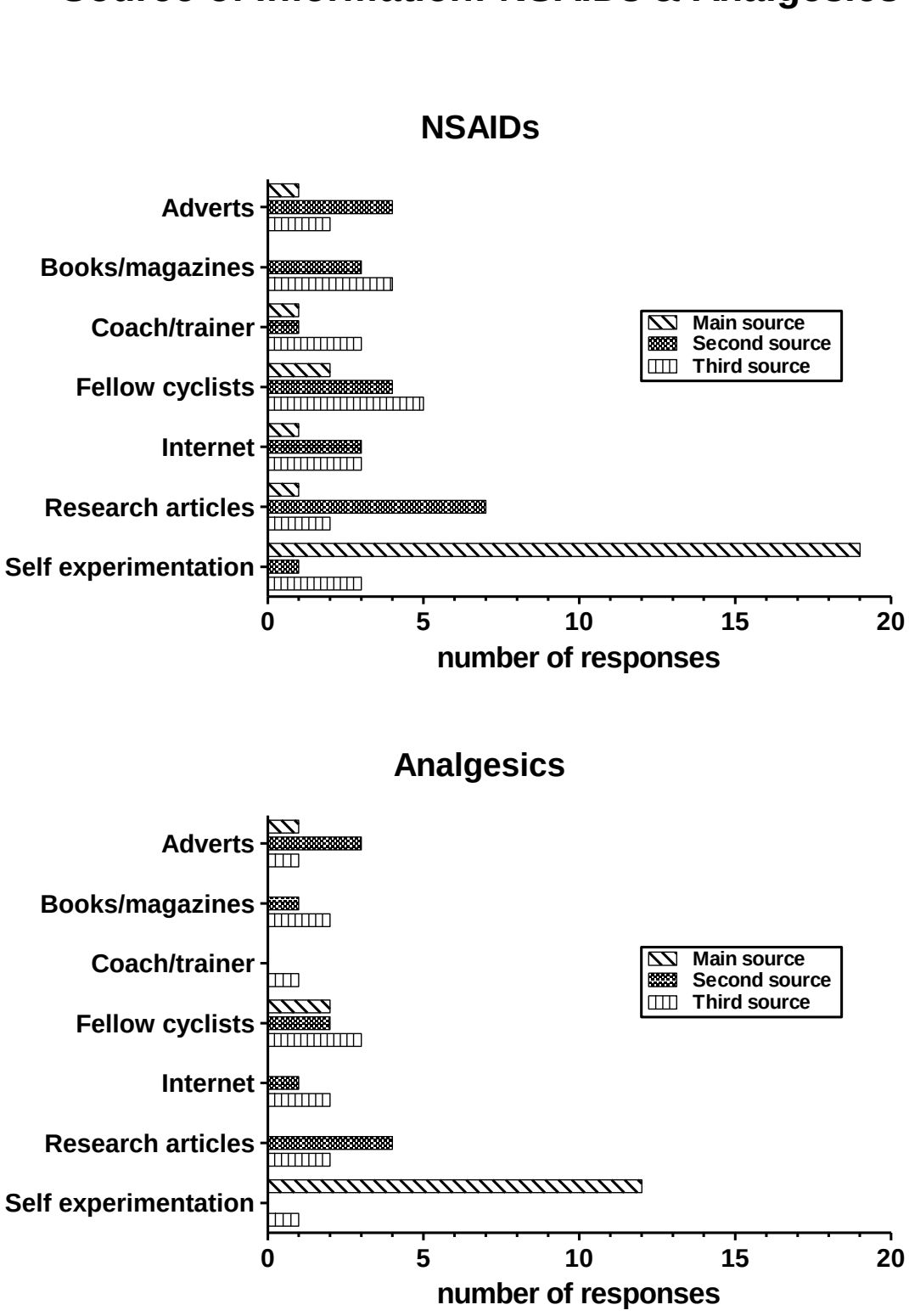

Figure 3.18: Sources of information influencing the use of NSAIDs and analgesics.

3.3.8.3 Illegal/banned ergogenic aids

Participant's primary source of information influencing the use of all the illegal/banned ergogenic aids (anabolic steroids n=1, HGH n=1, and cortisone n=1) was self-experimentation (Figure 3.19). Research articles (n=1), books/magazines (n=1), the internet (n=1) and fellow cyclists (n=1) were found to be the second most influential sources of information. The third most influential source of information for both anabolic steroids and HGH was the coach/trainer.

Source of Information: Illegal/Banned Ergogenic Aids

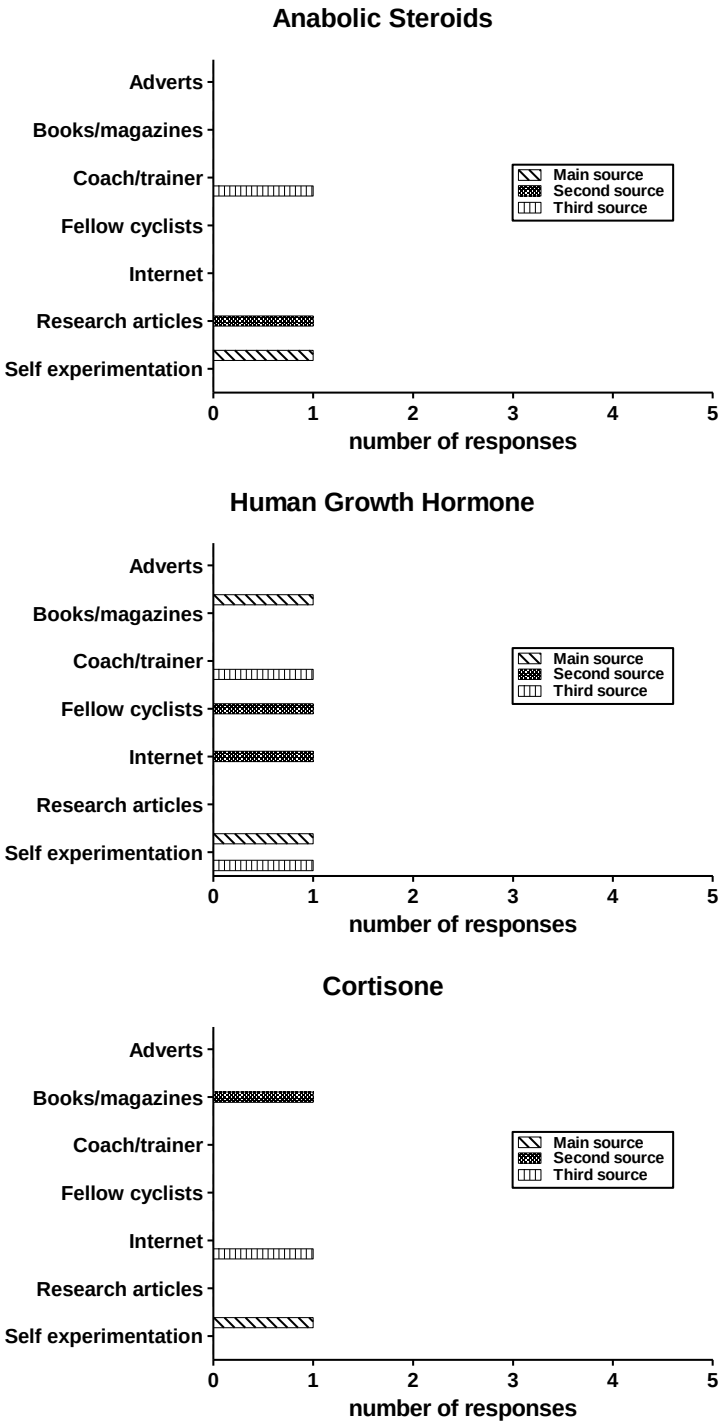

Figure 3.19: Sources of information influencing the use of anabolic steroids, HGH and cortisone.

3.3.9 Regression analyses of factors influencing the use of specific ergogenic aids

Forward stepwise regression analyses were performed to predict the probability of participants using a specific ergogenic aid. The predictor (independent) variables were age, BMI, education, preferred cycling event, cycling competitively, average weekly mileage (km.wk^{-1}), number of times a participant cycled per week (frequency) and the number of recovery days post competition (80 km to 100 km). The predictor variables were coded in Table 3.5 Section 3.2.5 (page 71). This study was unable to identify predictive factors for the use of sports drinks/gels, Vitamin B and NSAIDs. The non-significant regression analyses are presented in Appendix VII.

3.3.9.1 Nutritional aids

a) Carbohydrates and PRO

In ***Table 3.*** preferred type of event (p = 0.04) and the average weekly mileage (p = 0.03) were significant factors influencing the use of CHO and PRO. Road cyclists were half as likely (Exp(B) = 0.52) to use CHO and PRO compared to mountain bikers. Furthermore, participants who cycled more than 120 km.wk^{-1} were 2.28 times more likely to use CHO and PRO than those who cycled less than 119 km.wk^{-1}.

Table 3.19: Forward stepwise regression analysis of factors influencing the use of CHO and PRO (n=117; r=0.10).

Steps	Exp(B)	p-value	95% CI		Wald
			Lower	Upper	
Constant	1.25	0.64			0.22
Age	1.59	0.17	0.83	3.06	1.92
BMI	0.82	0.53	0.45	1.52	0.39
Education	1.06	0.90	0.43	2.62	0.02
Preferred cycling event	0.52	0.04*	0.28	0.96	4.44
Cycle competitively	1.21	0.59	0.61	2.37	0.29
Km.wk^{-1}	2.28	0.03*	1.09	4.74	4.82
Frequency per week	0.74	0.40	0.37	1.48	0.72
Recovery days post competition	1.04	0.92	0.51	2.11	0.01

b) Electrolytes

In Table 3.20, preferred type of event (p = 0.003) and the number of recovery days post competition (p = 0.02) were significance factors influencing the use of electrolytes. Road cyclists were approximately a third (Exp(B) = 0.39) less likely to use electrolytes compared to mountain bikers. Participants who recovered for less than three days after a competition were nearly three times more likely (Exp(B) = 2.65) to use electrolytes than those that recovered for more than four days.

Table 3.20: Forward stepwise regression analysis of factors influencing the use of electrolyte (n=83; r=0.173).

Steps	Exp(B)	p-value	95% CI		Wald
			Lower	Upper	
Constant	0.34	0.04			4.20
Age	1.85	0.07	0.95	3.61	3.29
BMI	1.03	0.94	0.53	1.97	0.01
Education	0.77	0.61	0.29	2.05	0.27
Preferred cycling event	0.39	0.003*	0.21	0.72	8.94
Cycle competitively	1.61	0.19	0.79	3.26	1.71
Km.wk^{-1}	1.47	0.33	0.67	3.20	0.94
Frequency per week	0.75	0.43	0.36	1.55	0.63
Recovery days post competition	2.65	0.02*	1.16	6.05	5.37

c) Amino acids

There was a tendency for competitive cycling to be predictive of the use of amino acids (p = 0.07); however this difference was not significant (Table 3.21). This may be due to the small amount of participants who reported using amino acids (n=32), which would correspond to the large CI observed (0.93 - 6.30).

Table 3.21: Forward stepwise regression analysis of factors influencing the use of amino acids (n=32; r=0.10).

Steps	Exp(B)	p-value	95% CI		Wald
			Lower	Upper	
Constant	0.10	0.00			10.21
Age	1.77	0.19	0.76	4.11	1.75
BMI	1.20	0.69	0.50	2.83	0.16
Education	0.43	0.29	0.09	2.03	1.14
Preferred cycling event	0.56	0.15	0.25	1.24	2.04
Cycle competitively	2.42	0.07	0.93	6.30	3.26
Km.wk^{-1}	0.70	0.50	0.25	1.97	0.46
Frequency per week	1.51	0.41	0.57	4.01	0.69
Recovery days post competition	1.23	0.71	0.41	3.72	0.14

d) Creatine

There was a tendency for average weekly mileage (km.wk^{-1}) to be predictive of the use of creatine (p = 0.08); however this difference was not significant (Table.3.22). As with amino acids, the small amount of participants reportedly using creatine (n=15) could cause this tendency. The large CI observed (0.86 - 17.64) would correspond to the small sample size.

Table 3.22: Forward stepwise regression analysis of factors influencing the use of creatine (n=15; r=0.09).

Steps	Exp(B)	p-value	95% CI		Wald
			Lower	Upper	
Constant	0.02	0.00			14.63
Age	2.67	0.11	0.79	9.01	2.50
BMI	1.68	0.39	0.51	5.56	0.73
Education	2.36	0.23	0.58	9.58	1.45
Preferred cycling event	1.84	0.33	0.54	6.29	0.94
Cycle competitively	1.04	0.95	0.29	3.72	0.00
Km.wk^{-1}	3.88	0.08	0.86	17.64	3.09
Frequency per week	0.52	0.31	0.15	1.85	1.02
Recovery days post competition	0.66	0.54	0.18	2.49	0.37

3.3.9.2 Pharmacological aids

a) Caffeine

In ***Table 3.***, age had a significant effect (p = 0.04) on the use of caffeine. The likelihood of someone older tha 40 years of age using caffeine were double that of someone younger than 39 years of age. Participants who cycled more than 120 km.wk^{-1} were twice as likely to use caffeine compared to those participants who cycled less than 119 km.wk^{-1} (p = 0.06); however this was not significant.

Table 3.23: Forward stepwise regression analysis of factors influencing the use of caffeine (n=93; r=0.13).

Steps	Exp(B)	p-value	95% CI		Wald
			Lower	Upper	
Constant	0.55	0.21			1.55
Age	1.99	0.04*	1.04	3.82	4.32
BMI	0.85	0.60	0.45	1.58	0.28
Education	1.17	0.73	0.47	2.94	0.12
Preferred cycling event	0.62	0.13	0.34	1.14	2.35
Cycle competitively	1.81	0.09	0.92	3.56	2.97
Km.wk^{-1}	2.04	0.06	0.97	4.29	3.49
Frequency per week	0.77	0.46	0.38	1.55	0.56
Recovery days post competition	0.99	0.99	0.48	2.07	0.00

b) Analgesics

In ***Table 3.***, the preferred cycling event had a significant effect (p = 0.02) on the use of analgesics. Road cyclists were 11.55 times more likely to use analgesics compared to mountain bikers. Although this factor was significant the CI was very large (1.45 - 91.98); therefore this result should be interpreted with caution.

Table 3.24: Forward stepwise regression analysis of factors influencing the use of analgesic (n=16; r=0.16).

Steps	Exp(B)	p-value	95% CI		Wald
			Lower	Upper	
Constant	0.01	0.00			12.02
Age	1.60	0.43	0.50	5.13	0.62
BMI	1.47	0.50	0.48	4.52	0.45
Education	2.01	0.34	0.49	8.31	0.92
Preferred cycling event	11.55	0.02*	1.45	91.98	5.34
Cycle competitively	1.04	0.96	0.29	3.68	0.00
Km.wk^{-1}	0.76	0.69	0.19	2.98	0.16
Frequency per week	0.52	0.34	0.14	1.95	0.93
Recovery days post competition	0.78	0.69	0.23	2.64	0.16

3.3.10 Summary of results

In summary, the participants in this study used an average of three ergogenic aids. Nutritional ergogenic aids were used by 42.0%; pharmacological by 23.4% and illegal/banned by 0.8% of the participants. Sports drinks/gels, CHO and PRO, caffeine and electrolytes were the most commonly used ergogenic aids.

Nutritional ergogenic aids (80.0%) were used mostly for both training and competition. Of the pharmacological ergogenic aids, caffeine and Vitamin B were mostly used for training and competition, whereas NSAIDs (66.7%) and analgesics (43.8%) were only used when participants were stiff and/or injured. The illegal/banned ergogenic aids were mostly used (66.6%) for competition. Cortisone was not reported to be used in training and competition.

The majority of the participants (58.3%) perceived that the seven ergogenic aids (sports drinks/gels, CHO and PRO, electrolytes, caffeine, Vitamin B, and anabolic steroids) increased endurance and time to fatigue. Thirty-three percent (33.3%) of participants perceived that the four ergogenic aids (NSAIDs, analgesics, HGH, and cortisone) decreased stiffness. Seventeen percent (16.7%) of participants perceived that the two ergogenic aids (amino acids and cortisone) decreased cellular damage and that the two ergogenic aids (creatine and anabolic steroids) increased strength and power. Participant's primary source of information influencing the use of all ergogenic aids (n=12) listed was self-experimentation. Less than 12.0% of participants sought information from research articles as their primary source of information.

Preferred cycling event, average weekly mileage, age and the number of recovery days were factors found to significantly influence the use of ergogenic aids. Road cyclists were less likely to use CHO and PRO ($p = 0.04$) and electrolytes ($p = 0.003$), but they were 11.55 times more likely to use analgesics ($p = 0.02$) compared to mountain bikers. Participants who cycled more than 120 $km.wk^{-1}$ ($p = 0.03$) were more likely to use CHO and PRO, and those that recovered for less than three days were more likely to use electrolytes ($p = 0.02$). Participants older than 40 years of age were twice as likely to use caffeine ($p = 0.04$). These results are discussed further in Section 3.4.

3.4 DISCUSSION

The purpose of this study was to describe the use of ergogenic aids in South African cyclists during training and competition. The discussion follows the order of presentation of the results in Section 3.3 (page 74). The literature has determined that investigating the use of ergogenic aids, both legal and illegal, is challenging due to the sensitive nature of the topic [127,188-192]. The diverse prevalence of use and lack of evidence, especially within the sport of cycling, can be attributed to the fact that doping and or the use of ergogenic aids, is illicit and most often concealed behaviour [8,9,66].

3.4.1 Participants

3.4.1.1 Sample size

The total sample size of this study was 207 participants, which provided a statistical power of approximately 90%. It must be recognised that over 2600 potential participants were emailed individually requesting their participation in the study along with the questionnaire link. A total of 58 cycling clubs and shops were contacted nationwide requesting the advertisement of the study in their respective newsletters. Five popular cycling media platforms also advertised the study link online. A total of 467 potential participants responded, which was narrowed down to 207 participants following a protocol of exclusion criteria. It is not possible to calculate a response rate for this study, based on the methods of distribution of the questionnaire and also the anonymity. The anonymity of the online questionnaire prevented the researcher from seeing the total number of people that accessed the link but that did not start the survey.

Low response rates are commonly reported in studies that investigate supplement use in athletes. Petroczi and Naughton[187] investigated the use of nutritional supplements among athletes over 18 years old sent out 2995 surveys to randomly selected participants via sports councils, and received 874 responses. Of those responses, only 520 met their criteria for further analysis. Brissonneau and Ohl[188] on the genesis and effect of French anti-doping policies in cycling, tried interviewing any professional cyclist between the years of 1960 and 2000 on doping behaviour. Of all the professional cyclists through those years, only 20 individuals were willing to take part in their study. Investigating the use of ergogenic aids both legal and illegal is challenging [127,188-192]. The literature has shown that athletes are reluctant to discuss their use of performance-enhancing products, particularly of illegal substances. Previous studies' response rates have shown to be similar to the seemingly low response rate in this current study [187,188].

The sample size of studies that investigated the use of ergogenic aids varied widely across the literature [190]. The difference in sample size was largely dependent on whether the studies were sport-specific or not. Studies targeting "*all sports*" had larger sample sizes of between 257 to 1810 athletes [64,187,190,193], whereas those specific to cycling had between eight and 70 participants [40,159,163]. Former studies that were sport-specific (power-lifters, n=26 and skiers, n=67) also had smaller sample sizes [112,184]. It is recognised that a larger sample size would have allowed for a more generalised representation of the South African cycling community.

3.4.1.2 Descriptive characteristics

There were no significant differences in age, body mass, stature, BMI and level of education between male and female participants. Participants were well-educated, with 88.9% having at least a tertiary school education. Only 30 participants were female. This finding might reflect different levels of participation in sport, but may be due to other factors related to the use of ergogenic aids.The mean age of participants was 44 years of age, suggesting that more adults over the age of 40 are participating in cycling. There are no previous studies in South African cyclists to compare data, however Australia demonstrated a similar pattern of cycling for age and gender, indicating fewer women and older adults cycling [194].

Most studies that investigated the use of performance enhancing substances amongst cyclists exclusively used male participants [5,9,188,191,193]. Previous studies that investigated the use of performance-enhancing substances among "all sports" included female participants [7,64,66,114,184,187,190,193]. The inclusion of females in this study is novel and would have allowed for a more generalised observation of the use of ergogenic aids across a cycling population, rather than a gender-specific observation. This study attempted to explore use in females but a larger sample size would have been needed. Sub-group analysis was only performed on descriptive characteristics, training and competition history and the type of ergogenic aids used. There were no significant differences between male and female participants across all the sub-group analyses. A consistent pattern of considerably lower rates of cycling amongst females has been shown in self-reported surveys [195]. A survey by the Australian Sports Commission found that females participated in cycling half as much as males [194,195]. There is a lack of evidence regarding nutritional intake, and physiological and performance characteristics of female cyclists [4].

Previous studies have used younger cyclists between 18 and 27 years old [5,9,188,191]. Where former professionals were included in the same age group, the focus was on their career [184,187,189]. This study did not exclude participants based on age, and showed results across a broader cycling population (18 to 65 years old).

3.4.2 Training and competition history

More than forty-four percent (44.4%) of the participants cycled competitively. The majority of participants preferred road cycling (61.3%) compared to mountain biking (37.7%). Previous studies have not included mountain biking in their investigation of the use of performance enhancing substances (ergogenic aids) in cyclists [5,9,17,188,191]. In general, road and track cycling are the most common disciplines reported in cycling literature [173]. A major limitation of studies investigating the relative characteristics of cycling and the effects of ergogenic aids on cycling performance, is the lack of consensus regarding the calibre of cyclists used or observed [66]. In an attempt to classify the participants in this study, a modified version of De Pauw et al[34] performance classification system was used. Participants were classified as ranging between trained and highly trained.

Studies that have investigated the use of performance-enhancing substances amongst cyclists used pre-professional, currently professional, or former professional cyclists only [5,9,17,188,191]. Studies that used trained or highly trained participants were not specific to cycling [7,187,190,193]. Previous studies have not investigated the use of performance enhancing substances in this calibre of cyclists specifically. This makes a direct comparison of results of different studies difficult.

The majority of the participants took two to three days to recover after a single day race and multi-stage race respectively. Cycling competitions are generally high-intensity in nature, and the literature states that the higher the intensity of the exercise bout, the longer the length of the recovery period needed [183]. It may be assumed then that a longer recovery period would be needed after a multi-stage race compared to a single day race, which was not found in this study. Recovery must be individualised and match the specific stress (i.e. single day race versus multi-stage race) to maximise the adaptations due to physical training [183].

3.4.3 Type of ergogenic aids used

The prevalence of doping varies widely across studies [193]. A review of self-reported studies between 1980 and 1996, estimated a 3% to 5% prevalence of doping for children and adolescents and 5% to 15% prevalence for adults ("*all sports*") [196].

Petroczi[7] carried out a questionnaire-based study on highly trained male college athletes ("*all sports*", n=174), which included past and current use of performance enhancing substances (both legal and illegal). Results showed a 7.5% current use of illegal drugs and a 2.5% current use of legal performance enhancing substances [7].

The true incidence of doping is thus difficult to define in cycling, as most studies are not specific to cycling [66]. Participants used an average of three ergogenic aids in this study (649 total instances/207 total sample size) [187]. If compared to the results in the Petroczi and Naughton [187] in 2008, the result from this present study, namely, 3.2 (number of instances/total sample size) for the average number of ergogenic aids, was similar.

Nutritional ergogenic aids were used by 42.0% of participants; pharmacological ergogenic aids by 23.4% of participants and illegal/banned ergogenic aids by 0.8% of participants. Sports drinks/gels CHO and PRO, caffeine and electrolytes were the most commonly used ergogenic aids. Moran et al[193] conducted a study using high performance athletes (n=375) older than 18 years old. Results demonstrated that 11% of the athletes self-reported to have knowingly used illegal substances to improve performance. These results were similar to those estimated by Laure[196], although Moran et al[193] included both recreational substances and performance-enhancing substances. When the use of recreational drugs (cannabis and alcohol) was removed, only 2.2% of the athletes admitted to using drugs to specifically enhance performance. This reported prevalence is comparable to the 2.8% adverse analytical findings across all sporting codes tested in the South African (Bloemfontein) laboratory in 2012 [197]. It is also comparable to the SAIDS 2011/2012 annual report, which found a 2.7% adverse analytical finding across 35 sporting codes [192]. More specific to cycling, the Union Cyclistse Internationale (UCI) reported a 1.1% rate of adverse analytical findings in 2012 [197]. This was the most comparable statistic to the findings in this study of 0.8% self-reported use of illegal/banned substances.

3.4.3.1 Nutritional ergogenic aids

Of the nutritional ergogenic aids listed, sports drinks/gels (90.8%), CHO and PRO (56.5%) and electrolytes (40.1%) were used for the most part, followed by amino acids (15.5%) and creatine (7.3%). There was no significant difference between gender and the use of nutritional ergogenic aids, although the majority of male participants used amino acids, while creatine was used exclusively by males.

Nutritional practices of cyclists are aimed at improving training adaptations and competition performance [4]. Carbohydrates represent an important fuel for both these components of cycling [4]. Burke[4] found that male cyclists generally exceeded the estimated intake of PRO for athletes who were highly trained.

There is not much data on the prevalence of using CHO and PRO for the specific purpose of enhancing performance. Research has shown that CHO ingestion can delay the onset of fatigue during prolonged cycling and thus provide an ergogenic effect through enhanced endurance performance [75,92,95,97]. The evidence for the consumption of electrolytes to enhance performance and improve recovery is lacking [126]. In spite of this, a large percentage of participants reported using electrolytes. Previous studies have not investigated the prevalence of electrolytes among cyclists, so the findings of this study cannot be compared to previous findings. Lentillon-Kaestner and Carstairs[9] interviewed young elite cyclists (n=8), with the aim to identify and understand the use of legal and illegal performance enhancing substances. All participants reported using performance enhancing products, and a wide variety of products was used. The nutritional products included amino acids, CHO and PRO [9]. There was also a high reported use of nutritional supplements among the cyclists.

The risk of taking nutritional supplements is high, as they often lead to inadvertent doping. Supplements may contain illegal substances which are not acknowledged on their label [9]. The world's largest supplement testing laboratory in Europe carried out a survey (HFL Sports Science 2013 European Supplement contamination survey) on 114 products from the top 24 supplement brands across Europe. Supplements tested included energy products, protein shakes, gels, powders, liquids and tablets. A 10% contamination rate was found, with capsules and tablets having the highest incidence of contamination [192]. The Cologne laboratory also carried out a survey of nutritional supplements which included vitamins, minerals, PRO, amino acids and creatine, purchased from 13 different countries. Altogether, 14.8% of the supplements tested contained illegal substances and a further 10% produced adverse analytical findings [42]. These two surveys highlight the risk involved in using nutritional supplements, not just for cyclists but for all athletes alike.

Petroczi and Naughton[187] described a 36.1% self-reported use of creatine among 520 high-performance athletes. Although the percentage is higher than this current study (7.3%), they had a much larger sample size which included athletes from "*all sports*". Cyclists only represented 8.7% of their total sample size. Similar to this study, the authors found that creatine was typically associated with males across all age groups. In contrast to the findings of this study, they found that athletes older than 40 years of age hardly used supplements (amino acids, creatine and PRO) at all.

3.4.3.2 Pharmacological ergogenic aids

Of the pharmacological ergogenic aids listed, caffeine (44.9%) and Vitamin B (26.6%) were used the most, followed by NSAIDs (14.5%) and analgesics (7.8%). Del Coso, Munoz and Munoz-Guerra[198] investigated the use of caffeine by athletes after its removal from the WADA list in 2004. Urine samples from 2004 to 2008 were used after official national and international competitions (n=20,686). More than seventy percent (73.8%) of the urine samples contained caffeine; cycling had the second highest levels of urine caffeine concentration. This figure was considerably higher than the reported use of caffeine by athletes (23.7%) in a previous study done in 2008. This did not differ signficantly, however, from Van Thuyne et al[199] who found that 74% of urine samples tested between 1993 and 2002 contained caffeine. This suggests that the use of caffeine has not changed in sports since its removal from the WADA list. Del Coso, Munoz and Munoz-Guerra[198] found no significant difference between males and females. The endurance sports, i.e. the triathlon, cycling and rowing, had the highest urine caffeine excretion after competition, suggesting that caffeine is used before and/or during competition [198]. After the removal of caffeine from the WADA prohibited list, an increase in the use of caffeine might have been expected [198]. The authors hypothesised that the former urinary threshold for doping (12 $ug.ml^{-1}$) was not restrictive enough to control the use of caffeine amongst athletes for the specific purpose of enhancing performance. The literature has evidently demonstrated that the beneficial effects of caffeine on performance can be met at doses that are well below the IOC urinary threshold [127,132,136].

Multivitamins have been reported to be used by 70.7% of athletes [187]. Previous studies have found that Vitamin C, multivitamins, mineral products, and caffeine are most commonly used by cyclists [6,9]. This is despite the lack of evidence for them enhancing performance (caffeine excluded). Most athletes have reported to take multivitamins (which include Vitamin B) for general reassurance and to avoid possible deficiencies [20].

The use of NSAIDs and analgesics is relatively unknown amongst cyclists. Most of the studies specific to cycling did not give reference to the use of these medications [9,17,188,191]. Huang, Johnson and Pipe[64] investigated the use of medication by Canadian athletes at the Atlanta (1996) and Sydney (2000) Olympic Games. Non-steroidal anti-inflammatories were the most commonly used medication at both games amongst athletes, with cycling being one of the sports in which a high prevalence of use was seen [64].

There was an overall prevalence of 33% in Atlanta and 38% in Sydney. This is much higher than the findings in this study, although it is a representation of athletes across "*all sports*" [64]. Laraschi et al[6] was the one study specific to cycling in which the use of prescription drugs was reportedly a common occurrence among young elite cyclists, specifically the use of NSAIDs.

3.4.3.3 Illegal/banned ergogenic aids

A total of four participants in this study self-reported to be doping. Human growth hormone (1.0%), cortisone (1.0%) and anabolic steroids (0.5%) were used; EPO and blood transfusions were not reported to be used by any of the participants in this study. According to the WADA 2012 report, out of all the Olympic sports, cycling had the third highest number of samples analysed- football and athletics respectively had the highest number of samples analysed [197]. Three South African cyclists in the 2011/2012 year tested positive for illegal/banned substances and were subsequently prosecuted [192]. Two of the cyclists tested positive for anabolic steroids and one for stimulants [192]. Although this may seem similar to the current study's results on reported doping, there are some important points to consider. Firstly, surveys of this nature present limitations of under-reporting, and secondly, potentially far more cyclists are doping, but are for various reasons undetected [5,9,66,127,187-191,193,198]. In addition, SAIDS drugs-test cyclists' considered to be "*professional*", whereas the participants in this study represented a different calibre of cyclists, who are not generally flagged for drug testing.

Recent studies have evaluated the incidence of anabolic steroids in various age groups and across various sports and sporting levels [127,144,174]. Although the exact incidence varies between all studies and across different groups, there is great concern regarding the increase in prevalence, especially amongst high school students [127]. The approximate prevalence of anabolic steroid use among cyclists is unknown and most evidence is based on anecdotal data.

The literature suggests that HGH is abused by numerous cyclists; however, a prevalence rate has not been documented to the knowledge of this researcher [154]. Lentillon-Kaestner, Hagger and Hardcastle[5] recognised that of the cyclists interviewed in their study, there was a consistent reference to EPO, HGH and cortisone with regards to doping. Evidence for cyclists using HGH has generally emerged from media reports on the positive testing of professional cyclists. The Festina team scandal was one such highly publicised event, in which the cyclists and the physiotherapist were caught carrying a large number of ampoules containing HGH, at the 1998 Tour de France [154].

Though only 1.0% (n=2) of participants admitted to using cortisone in this study, research has previously reported the frequent use of cortisone in cycling through the misuse of TUE certificates to improve performance [5,9,17]. The South African Institute of Drug-Free Sport reported receiving 13 TUE certificates during the 2011/2012 year from cycling specifically. Rowing and swimming had the highest incidence of TUE certificates [192]. It was not clear from the data of this study whether the participants using cortisone had TUE certificates or not.

In this study EPO and blood transfusions were not reported to be used. This finding is congruent with the literature. Among the cycling studies, the use of EPO and blood transfusions was minimal. The high costs and difficulties in obtaining the substances and instruments, along with the intricacies involved in the administration and the storage of the products were restricting factors [5,9]. Lentillon-Kaestner, Hagger and Hardcastle[5] found that EPO was used more at a professional level, as a result of these usage constraints. The participants of this study were only classified as trained/highly trained cyclists, which may potentially be the reason that the results of this study had no reported use of EPO and blood transfusions. The misuse of EPO as an ergogenic aid has been projected to range between 3% and 7% in elite endurance athletes ("*all sports*") [157]. There is a considerable amount of clinical evidence supporting the ergogenic benefits of EPO on endurance performance as a result of the increases in haemoglobin, haematocrit and VO_{2max} [157,166,168-171].

Since all the doping scandals, regulations and preventative actions have been increased [5]. Across the studies reviewed, there was consensus that the sport has evolved since 1998 (Festina team scandal) and doping is now less of an organised team practice and rather a more individualised deed [5,9,17,188-191,193]. Although cycling, as a sport, is scrutinised and stigmatised in the media to be "*the doping sport*", WADA, SAIDS and the UCI are finding low rates of adverse analytical findings. This finding can be seen as similar to the low percentage of participants in this study who admitted to doping. It can be argued that, as doping is now perhaps more individualised, and cycling is subjected to close scrutiny (cycling had the third highest amount of tests analysed by WADA in 2012)[197], those cyclists that are doping, are more cunning and secretive about their behaviour, making true incidence rates hard to obtain. The Festina Affair might thus actually have been a catalyst for more sophisticated doping regimes as evidenced by iconic individuals and popular teams over the last decade.

Of the self-reported use of illegal/banned ergogenic aids in this study, all were from male participants. In general this proved non-significant in this study, an epidemiological review by Laure[196] found similar results. Across all the reviewed studies, males displayed higher usage of illegal/banned substances than females [187,189,190,193].

Moran et al[193] also found that males had a more positive attitude towards doping compared to females. There is literature available that provides insight into the differences in use of ergogenic aids and gender, however whilst acknowledging the theories put forward, no clear theory has yet to predict doping behaviour related to gender type [189].

3.4.4 Pattern of use and perceived effects

Research investigating the tactical strategies employed by athletes is lacking, especially amongst cyclists, as to when certain ergogenic aids are used. Through clinical trials, the literature has described and recommended when and how particular ergogenic aids should be taken to obtain the maximum performance enhancing benefits [66,75,103,133,146].

3.4.4.1 Nutritional ergogenic aids

Eighty percent (80%) of the nutritional ergogenic aids were used for both training and competition (Section 3.3.5, page 83). The majority of participants believed that sports drinks/gels, CHO and electrolytes worked by increasing endurance and time to fatigue. The literature has demonstrated the ergogenic effect of CHO on endurance performance by increasing time-to-fatigue [75,92,95,97]. Carbohydrates are recommended to be consumed three to six hours before an event, and during exercise that lasts longer than 90 minutes [66,72,75,76,78]. Whether CHO is consumed in the liquid (sports drinks/gels) or solid form, the ergogenic benefit is not affected [80].

Amino acids and creatine were used more frequently before training and competition. Amino acids were perceived to decrease cellular damage and creatine to increase strength and power. A relationship can be made as to when creatine was most used and its perceived effect. As for amino acids it may have been assumed that participants would consume them after training and competition to enhance recovery. A possible explanation may be the use of unreliable information resources used by participants.

3.4.4.2 Pharmacological ergogenic aids

Caffeine and Vitamin B were mostly used before training and competition, which correlated to the participants' perception that they increased endurance and time-to-fatigue. This finding also relates to the suggestion by Del Coso, Munoz and Munoz-Guerra[198] that caffeine is consumed before/during competition.

The literature suggests that caffeine be ingested one hour before exercise for maximum benefit [133]. Coffee, tea and soft drinks are considered weaker sources of caffeine compared to concentrated caffeine (capsule) [130]. Yet participants reported using caffeine mostly through the consumption of coffee. Currently there is little literature to support supplementation with vitamins, minerals and anti-oxidants for athletes following a normal healthy diet. There is also little scientific evidence showing any benefit of vitamin supplementation on exercise performance in endurance athletes [11,20,42,64]. As seen from the results, Section 3.3.8 (page 112) a very low percentage of participants actually sought information from reliable resources. This may influence the pattern of use as seen above.

Non-steroidal anti-inflammatories and analgesics were used mainly when participants were stiff and/or injured, which correlates to the perceived effect of decreasing stiffness. This may suggest that participants were using them to enhance the recovery process after a bout of intensive training or competition. It does not, however, indicate whether participants were using these medications during exercise, which is of concern because of the potential interactions that may occur with exercise and the use of medication. Despite the lack of scientific evidence demonstrating ergogenic effects of vitamins, NSAIDs and analgesics on sports performance, 48.8% of the participants in this study reported using these products.

3.4.4.3 Illegal/banned ergogenic aids

The illegal/banned ergogenic aids were mostly used (66.6%) for competition. Cortisone was not reported to be used in training or competition, but only when participants felt stiff and/or were injured. The illegal/banned ergogenic aids had more than one commonly perceived effect of which one included "*unsure*". This may suggest that knowledge about these ergogenic aids is poor. This is concerning since, firstly, there is poor evidence supporting their effect on endurance performance, and secondly, because of the consequential health effects related to their use [11,18,66,103,144,174].

3.4.5 Perceived effects on performance

Fifty-eight percent (58%) of participants perceived that the ergogenic aids used increased endurance and time to fatigue. Thirty-three percent (33.3%) of participants perceived that they decreased stiffness and 17% perceived that they would decrease cellular damage and increase strength and power.

All the cyclists in the Lentillin-Kaestner and Carstairs[9] study expected the methods and substances that they used would have beneficial effects on their performance. They had, however, not quantified or evaluated them. Athletic performance may be improved by expectancy effects [200]. Eighty-nine percent (89%) of athletes surveyed professed positive effects from ergogenic aids on their performance [200,201]. Of all the ergogenic aids listed in this study, besides for creatine and anabolic steroids, a percentage of participants were grouped in the "*no/no*" domain (Section 3.3.7, page 110). This is an interesting observation, which raises questions as to what the motivation is behind the continued use of a substance. The intense marketing and promotion of products may drive the continued use, or athletes continue to use substances out of habit. Eight percent (8%) of participants in a previous study reported "*common habit*" as a reason for doping [6]. Another theory suggests that athletes become psychologically dependent on a substance. If participants have taken the substance previously and had a good race, there is then a notion of belief that they must always take it, because without it they are unlikely to do well again [9]. Future research needs to investigate the motivation for the use of specific ergogenic aids in order to better understand the athletes' intentions and behaviour.

3.4.6 Sources of information

Cycling has been described in the literature as being a "*coherent community built on shared ideals*" [17]. This description of cycling aptly relates to the findings in this study, highlighting the impact fellow cyclists have on each other's behaviour due to the tight nit nature of the sport (especially road cycling).

Participants using ergogenic aids mainly obtained information from "*questionable*" resources, such as self-experimentation (51.7%) and fellow cyclists (13.7%) [59]. Reliable resources, such research articles were used by less than 12.0% of participants. Results on the pattern of use and perceived performance effects (Section 3.3.5, page 83 and Section 3.3.7, page 101) are in line with findings in the literature showing that the sources of information used by participants were mainly non-medical [6]. Information provided by fellow cyclists, books/magazines, coaches/trainers, the internet and adverts does not mean it is based on scientific research; therefore the advice may be inaccurate or inappropriate [55]. The use of a substance based on fictional information, along with the influence of marketing leads to a number of ergogenic aids being used inappropriately, as seen in this study.

For example; self-experimentation and fellow cyclists were the two most influential sources for the use of caffeine. Seventy-two percent of participants used coffee as a means to enhance performance despite research clearly stating that it is not the ideal method to obtain an ergogenic effect [42].

Research articles were found to be the second most influential source of information for the reported use of creatine, Vitamin B, NSAIDs, analgesics and all the illegal/banned substances. This finding is surprising as research based on scientific trials has demonstrated very little evidence for these ergogenic aids, especially in endurance cycling [4,15,20,42,64,65,121,126,144]. Interest in ergogenic aids may stem from the large amount of media attention given to doping in cycling [5,9]. Primary sources of information for the participants of the Lentillain-Kaestner and Carstairs[9] study included fellow cyclists (former professionals), books about doping and the internet. The more experienced cyclists were reported to be the most influential in promoting the use of illegal/banned substances to other cyclists [9]. The temptation for doping was also greater when the young cyclists spent time with fellow cyclists who were doping [5,9]. Lentillon-Kaestner, Hagger and Hardcastle[5] found that since all the doping scandals in the media, team staff and doctors have backed off from placing pressure on professional cyclists to dope. In contrast; Schnieder[17] found that coaches, managers, doctors and masseurs had a substantial influence on the use of illegal/banned performance enhancing substances at the professional cycling level.

3.4.7 Factors predicting the use of ergogenic aids analyses

3.4.7.1 Descriptive characteristics

Del Coso, Munoz and Munoz-Guerra[198] found that athletes over 30 years of age had significantly higher levels of urine caffeine concentration compared to athletes younger than 20 years of age. This supports the significant association between age and the use of caffeine as found in this study. Participants older than 40 years old were twice as likely to use caffeine than participants younger than 39 years old. The authors hypothesised a number of reasons for the relationship between age and the use of caffeine [198]. Firstly, the ingestion of tea and coffee may increase with age, although there are no scientific data confirming this. Secondly, the sports-speciality may be related to age. This is supported by Rissel, Munro and Bauman's[194] finding of a greater number of older adults who are cycling compared to the number of younger adults. Thirdly and finally, perhaps the increased caffeine consumption in older athletes is an attempt to negate the decline in physiological capabilities related to the natural aging process itself [198]. All of the reasons above are mere speculations; further investigation into the true reasons for the higher caffeine use is still required.

The level of education did not play a significant role in influencing the use of specific ergogenic aids amongst participants. Of the previous studies reviewed, not one had investigated the relationship between level of education and the likelihood of using performance enhancing products [5,9,17,188,191].

3.4.7.2 Cycling discipline

Road cyclists were half as likely to use CHO and PRO and approximately a third less likely to use electrolytes compared to mountain bikers. Mountain biking generally entails off-road terrain, characterised by dirt and gravel roads as well as narrow trails and open fields. It typically involves a large proportion of uphill climbing followed by technical descents [202]. Lee et al[202] found that mountain bikers were lighter and significantly leaner than road cyclists when they compared physiological characteristics.

This is surprising when considering the associations found in this study. As a result of the factors discussed in Section 2.2.2 (page 6), it may be assumed that mountain bikers are more weight conscious due to the excessive mountainous terrain. Limited feeding time whilst cycling may also be expected in mountain bikers due to the technical skills the sport requires [202]. Perhaps as a result of the nature of the sport, mountain biking could be considered a more demanding endurance sport compared to road cycling, and thus ingestion of fuel in the form of CHO, PRO and electrolytes is greater in order to sustain energy levels and resist fatigue [202].

Road cyclists were almost 12 times more likely to use analgesics compared to mountain bikers. The large confidence interval however, strongly suggests that this finding be interpreted with caution. As such no, further discussion regarding this underlying association in this study is warranted. No previous study, to our knowledge, has investigated the difference between nutritional intake and characteristics in road cyclists and mountain bikers. Thus a comparison of the associations found in this study between the two cycling disciplines is impossible.

3.4.7.3 Training factors

Participants who cycled more than 120 $km.wk^{-1}$ were 2.28 times more likely to use CHO and PRO than those who cycled less than 119 $km.wk^{-1}$. The higher the demands of training the higher the energy demand on the body, and thus the more fuel the body needs to sustain energy levels, optimise training and enhance performance. This association is supported by literature relating increased fuel requirements with increased training intensity [86].

Participants who recovered for less than three days after a competition were nearly three times more likely to use electrolytes than those that recovered for more than four days. The majority of the participants (77.3%) took less than three days recovery post competition (80 km to 100 km). This association found between the use of electrolytes and enhanced recovery (as fewer number of recovery days were taken), is supported by the literature. Fallowfield et al[85] were the first to demonstrate that the ingestion of a CHO-electrolyte drink after exercise enhances recovery.

Interestingly, the most common perceived effect of electrolytes (60.8%) was that they improve endurance and time to fatigue. Furthermore, electrolytes were mostly reported to be consumed before/during training and competition. These findings contradict the subsequent notion that participants were using electrolytes to enhance the recovery process. The top two sources of information influencing the decision to use electrolytes were self-experimentation and fellow cyclists. Participants did not obtain information from trustworthy scientific sources; hence the reasons associated with the use of electrolytes were not correlated to the literature.

The main predictor variable influencing the use of specific ergogenic aids was preferred cycling event (road or mountain biking). While a participant's competitiveness did not reach significance, the p-values had a tendency to approach significance more often when compared to other variables. Laure[10] demonstrated a 4.8% prevalence of doping at a recreational level and 10.8% prevalence in competition. It was proposed that the level of competition influenced doping behaviour. At a national and international level of competition, 17.5% declared doping compared to 10.3% at local competitions. However, this study was not specific to cycling and different sports are considered to have different doping cultures [10]. Athletes of all levels will be driven to improve and reach higher levels of achievement [66]. The literature has shown that the use of illegal/banned ergogenic aids does not only exist at the professional level of cycling [5,9,66]. Athletes at the recreational level are no longer competing against themselves for self-fulfilment, they are competing against someone else and there is inevitably always someone better, faster or stronger [66]. Perhaps it is this which drives curiosity for alternative means to improve performance.

If it can be assumed that all elite cyclists train as smartly and as intensely as they possibly can, then it can be assumed that all recreationally competitive (trained/highly trained) cyclists do too. The difference is that at the recreational level most athletes are working full time. The frequency and duration of training may thus be limited, potentially further influencing the use of performance enhancing products, where training is deemed insufficient to improve performance alone [40].

3.4.8 Limitations of the study

The prevalence of ergogenic aid use and doping in the literature has mainly been measured through questionnaires of self-reported use, interviews with athletes, questionnaires about use by other athletes and the number of positive doping test results [7,64,66,114,184,187-191,193]. All methods of measurement to determine the prevalence of ergogenic aid use and specifically doping will present limitations as discussed in Section 2.9 (page 55) [127,187-191,193].

While the sample size was adequate, and larger than most studies [5,9,170,188,191], once sub-group analyses were performed for gender and the specific ergogenic aids, the numbers may not have been large enough to provide adequate statistical power. It is recognised that the researcher could have potentially recruited more participants for the study through reminder emails, with an apology if participants had completed the questionnaire already. Reminders were only sent to cycling clubs, shops and media platforms. A larger sample size would have allowed for better representation of the South African cycling population. Due to the voluntary nature of the questionnaire the study sample may represent bias. Individuals who volunteer to participate in a study are often different from non-volunteers. Volunteers often tend to be more concerned about their health and more motivated [182].

The study's sample may represent bias towards "*responders*". Emails requesting participation in the study were sent to prospective participants from a database of individuals who had responded to a previous cycling questionnaire. Thus there was an increased likelihood that they would respond to this questionnaire. It can be argued that the topic of the questionnaire was completely different to this study and that individuals presumably gave their contact details because they had a chance of winning something. The participants of this study were well informed that there were no direct benefits for completing this study's questionnaire.

The study's sample may also represent bias towards cyclists in the Western Cape. The majority of cycling clubs and shops contacted (38%) were situated in the Western Cape. The extent to which this bias exists is speculative as the questionnaire was completely anonymous, and there was no way of determining where participants resided. This study also did not clearly define a population. A more stringent level of competitiveness, gender and/or age group definition for inclusion would have potentially improved the ability to compare and relate findings with previous studies; however this would have reduced the generalisability of the study findings.

In an attempt to secure the participants' trust and increase credibility of the questionnaire data, the following steps were taken, which were in line with those taken in previous studies of the same nature and those recommended in the literature concerning online surveys [5,55,78,161,175,176].

Firstly, the aim of the research, and what the data was going to be used for, was clearly outlined on the opening page of the online questionnaire. Secondly, all participants were informed that their responses were completely anonymous, that IP addresses could not be traced, and that responses would not be sent to any testing authorities. Given the sensitivity of the information received from participants, this was essential to communicate [5]. Thirdly, participants were informed that they were able to stop and/or exit the online questionnaire at any point without sanction or prejudice, before providing their informed consent.

Furthermore in an attempt not to bias potential participants, the questionnaire had a customised language selection. Participants were also able to complete the questionnaire easily as they only viewed questions which were applicable to them [179]. In an effort to decrease non-responses and missing data, most questions were manipulated to ensure participants answered the questions before advancing forward [179].

3.4.9 Summary and recommendations

Results of this study show that trained and/or highly trained cyclists use an average of three ergogenic aids, and that nutritional ergogenic aids are the most commonly used aids. Sports drinks/gels had the highest reported use, followed by CHO and PRO, caffeine and electrolytes. Four participants self-reported to be doping with anabolic steroids, HGH and/or cortisone.

This is the first study, to this researcher's knowledge, that investigated the pattern of use of ergogenic aids in cyclists. The pattern of use was variable; however 75% of the ergogenic aids listed were mostly used in training and competition. The two main predictor variables influencing the use of specific ergogenic aids were preferred cycling event and average weekly mileage. The findings on pattern of use and perceived performance effects, suggest inappropriate use and poor understanding of many of the ergogenic aids used. The misconceptions and inaccuracies correlate to the "*questionable*" information resources used by participants [85].

There are two novel aspects of this study. This is the first study that has investigated the type and pattern of use of ergogenic aids in South African cyclists. This study also has the largest sample size investigating the use of ergogenic aids in cycling. Future studies should continue to include more female cyclists and mountain bikers. The inclusion of females and mountain bikers will allow for a more generalised observation of the use of ergogenic aids across a cycling population, rather than a gender specific or discipline specific observation. As discussed in Section 3.4.1.2 (page 129) this study attempted to explore use in females and different disciplines but a larger sample size is needed to improve statistical power.

A major issue regarding the investigation of the use of ergogenic aids in the literature is that studies have included and categorised aids differently. Standardised classifications of ergogenic aids will enable researchers compare findings between studies [53].

Based on the findings of this study, it is evident that the consumption of nutritional and pharmacological ergogenic aids is high and often concomitant. Educational interventions are needed in South Africa to ensure cyclists are appropriately informed about the use of ergogenic aids. This highlights the importance of regulatory authorities (e.g. SAIDS) to take responsibility in ensuring that cyclists are informed about legal ergogenic aids, rather than monitoring and censoring use of illegal/banned aids only. Recently SAIDS advertised the implementation of a proactive anti-doping and education programme targeted at professional and youth football players on the risks associated with sports supplements use [192]. A programme similar to this, targeting cyclists and educating them on the use of legal ergogenic aids is recommended. The collaboration of SAIDS and Cycling South Africa on an initiative such as this would perhaps make funding more feasible.

It may be challenging as an individual cyclist to enter a sporting discipline where there are anecdotes, misconceptions and inaccurate information regarding efficaciousness of ergogenic aids. More research is needed to obtain an in-depth understanding of knowledge, attitudes and behaviours regarding the use of ergogenic aids. This information can be used to assess the value of current interventions, as well as to support the need for strong educational initiatives to positively influence the safe and appropriate use of ergogenic aids in cycling.

CHAPTER 4: SUMMARY AND CONCLUSION

Cycling is largely an endurance event which pushes cyclists to exhaustion and fatigue in both training and competition [3]. Ergogenic aids are misused to address the metabolic disturbances that may result from high intensity training and competition, in an attempt to improve performance and enhance recovery [15,16]. There is widespread use of nutritional and pharmacological ergogenic aids despite the poor evidence for their ergogenic effect on cycling performance [64]. Anecdotal evidence far precedes scientific evidence in relation to the benefits of using most ergogenic aids [6,11]. This has contributed to inappropriate use of ergogenic aids seen in this study amongst cyclists and therefore an increased risk of health related side-effects [12].

The overall aim of this study was to describe the use of ergogenic aids in South African cyclists during training and competition. Based on the evidence provided in this dissertation, the study objectives as described in Section 1.2.2 (page 2) may be answered as follows:

(1) To obtain information on ergogenic aid use in male and female South African cyclists, with regard to the type of ergogenic aids used, and the pattern of use during training and competition.

In this study, participants used an average of three ergogenic aids, indicating that ergogenic aids are used in combinations [158]. Concomitant use of ergogenic aids can be dangerous as a result of interactions causing undesired health related side-effects [6,187]. Nutritional ergogenic aids were used the most, followed by pharmacological ergogenic aids. The reported use of illegal/banned substances was low, and may not provide an accurate reflection of the current practice. Of all the ergogenic aids listed sports drinks/gels had the highest self-reported use, followed by CHO and PRO, caffeine and electrolytes. Four participants reported the use of anabolic steroids, HGH and/or cortisone. Additional ergogenic aids that were used by participants in descending order included; Vitamin B; amino acids; NSAIDs; analgesics and creatine.

There was a variable pattern of use for all categories of ergogenic aids however they were used throughout training and competition. The majority of participants reportedly used NSAIDs, analgesics and cortisone only when they were stiff and/or injured. The limitation is that this does not reflect whether participants are using these aids during exercise. The variable pattern of use may reflect inadequate understanding of the proposed mechanisms of action of many of the ergogenic aids, and may also introduce potential for reduced efficacy associated with inappropriate use.

(2) To determine South African cyclists' perception of the effect of ergogenic aids.

The majority of participants (58.3%) perceived that the ergogenic aids used increased endurance and time to fatigue. Thirty-three percent of participants perceived that they decreased stiffness, 17% perceived that they decreased cellular damage and increased strength and power. The illegal/banned ergogenic aids had more than one commonly perceived effect. This suggests that knowledge about these ergogenic aids is poor, which is concerning as participants were continuing to use them. Participants in this study had misconceptions regarding the effect of ergogenic aids. Participants' perceived effects of many of the ergogenic aids did not correlate to the effects shown in the literature but rather to anecdotal evidence. Consequently these misconceptions might lead to the ineffective and dangerous use of aids during cycling training and competition.

(3) To determine the sources of information influencing South African cyclists' use of ergogenic aids.

Self-experimentation and fellow cyclists were determined to be influential sources of information in the decision-making process regarding the use of specific ergogenic aids. Less than 12.0% of participants ranked research articles as their primary source of information. This raises even more concern given the observation that the participants of this study had good instruction levels (88.9% with at least a tertiary degree) [(6)]. The variable pattern of use and misconceptions of perceived performance effects observed in the findings might be consequential to the non-medical sources of information used by participants.

Research articles were found to be the second most influential source of information for the reported use of creatine, Vitamin B, NSAIDs, analgesics and all of the illegal/banned substances. This was interesting, as some of the perceived effects did not correlate to the literature. This discrepancy might exist as a "*research article*" was not defined for participants. Participants might have read expert opinions on the internet and believed that those were research articles. The source of information needs to be clearly explored to understand where cyclists are getting their information. Many studies in the literature reported athletes inappropriate use of information resources [(12,55,59)].

It is unsafe for athletes to use ergogenic aids without a full evaluation and understanding of the associated benefits and risks [12]. Educational interventions are needed to enable cyclists to be appropriately informed about the use of ergogenic aids.

(4) To explore the socio-demographic and training factors that may predict the use of ergogenic aids, such as age, level of education and training and competition history.

There was a significant association between the use of caffeine and age, with a higher prevalence of use in participant's older than 40 years of age. This is an interesting observation which may be linked to the psycho-stimulant effects of caffeine [203]. Caffeine has been found to increase alertness and quicken reaction time [203]. Older adults may feel an increased need for these effects compared to younger participants. Appropriately, road cycling requires the skill of drafting that necessitates concentration and mountain biking presents technical terrains requiring quick reaction times. There was a significant association between mountain biking and the use of CHO and PRO and electrolytes. Due to the large amount of climbing and technical aspects of mountain biking, it takes much longer to cover the same distance of that on the road. This would explain the increased use of nutritional ergogenic aids observed in mountain bikers. Carbohydrates and PRO were also significantly associated with increased average weekly mileage (more than 120 $km.wk^{-1}$). This suggests that participants who trained more consumed more nutritional aids. The nutritional requirements of an athlete increase as training duration, frequency and intensity increase [86]. The number of recovery days taken after a competition was also significantly associated with the use of electrolytes. Those participants using electrolytes took fewer number of recovery days. The literature is conflicting regarding the ability of electrolytes to enhance performance [126]. The use of a CHO-electrolyte drink however has shown beneficial effects on recovery time [82,85].

Based on the findings of this study it is recommended that SAIDS and Cycling South Africa collaborate to review current strategies of anti-doping and programmes within the "*I Play Fair*" concept. The results of this study show that there is a high prevalence of use of legal ergogenic aids, with very little understanding of the beneficial effects and potential risks. The information resources used are mainly non-medical and inaccurate, propagating misconceptions with the cycling community. Educational initiatives focusing on the use of nutritional and pharmacological ergogenic aids are needed to ensure safe and appropriate use amongst cyclists and to facilitate maximum efficacy of use.

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APPENDIX I

UNIVERSITY OF CAPE TOWN

Faculty of Health Sciences

Department of Health and Rehabilitation Sciences

Divisions of Communication Sciences and Disorders; Nursing and Midwifery; Occupational Therapy; Physiotherapy; Disability Studies

F45 Old Main Building, Groote Schuur Hospital
Observatory, Cape Town, W Cape, 7925
Tel: +27 (0) 21 406 6401/ 6428/ 6628/ 6534
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QUESTIONNAIRE BACKGROUND AND INFORMED CONSENT

(Template of the online version: page one of the questionnaire)

Thank you for taking the time to complete this questionnaire which would greatly add to the body of knowledge and literature regarding the use of performance and recovery products by cyclists.

This survey will take 40 minutes to complete (maximum)

Please follow the instructions carefully.

Sections A and B are compulsory. In Section C, please answer only the questions relevant to you.

Each questionnaire will be coded (allocated a number) to ensure confidentiality and anonymity.

We understand the need for extreme sensitivity as some of the questions below entail information surrounding illegal/banned substances. We take confidentiality and anonymity very seriously. The information collected will only be used for research purposes. All referring URL's and IP addresses of respondents are hidden and therefore cannot be traced by any means.

Information obtained from the questionnaires will not be provided to any regulatory body, such as SAIDS and Cycling South Africa.

Please tick (√) the appropriate box to indicate your answer when filling out the questionnaire.

Please complete sections A, B and C

Section A: Demographic data

Section B: Training and Race history (over the last 12 weeks)

Section C: Use of performance and recovery products (as CURRENTLY applicable)

If you have any questions you would like answered before completing this questionnaire please feel free to contact the following people:

Ashleigh Hansen (Principle Investigator).....ash_hansen10@hotmail.com

Dr Theresa Burgess (Supervisor).....theresa.burgess@uct.ac.za

Professor Andrew Bosch (Co-Supervisor).....andrew.bosch@uct.ac.za

Professor Mike Lambert (Co-Supervisor).....mike.lambert@uct.ac.za

Any questions or concerns regarding your rights as research participants please contact:

Human Research Ethics Committee (HREC REF: 255/2012)....marc.blockman@uct.ac.za

Participation in this study is voluntary.

You have the right to withdraw from this study at any time without reason or prejudice.

You will be required to indicate informed consent by ticking the appropriate box below.

Please note that by accepting the option to participate in the study you are providing your informed consent.

This will then lead you to the questionnaire.

Would you like to participate in this study?

○ Yes

○ No

APPENIDX II

UNIVERSITY OF CAPE TOWN

Faculty of Health Sciences

Department of Health and Rehabilitation Sciences

Divisions of Communication Sciences and Disorders; Nursing and Midwifery; Occupational Therapy; Physiotherapy; Disability Studies

F45 Old Main Building, Groote Schuur Hospital
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Dear Prospective participant

MASTERS THESIS RESEARCH: THE USE OF ERGOGENIC AIDS IN CYCLISTS

I am a Masters of Philosophy in Sports Physiotherapy student at the University of Cape Town, Division of Physiotherapy. I am conducting a study, as part of my degree, to investigate the use of ergogenic aids by cyclists. This study has been given ethics approval by the University of Cape Town, Faculty of Health Sciences Human Research Ethics Committee (*HREC REF: 255/2012*).

It is well known that athletes seek out ergogenic aids to enhance sporting performance. Ergogenic aids can be defined as "any means of enhancing energy utilisation, including energy production, control, and efficiency". Ergogenic enhancing practices include well acknowledged techniques of carbohydrate loading prior to an event, use of supplements such as creatine, caffeine and multi-vitamins as well as the use of growth hormone and blood doping.

There is little available literature on the use of ergogenic aids by cyclists. The purpose of this study is to gain a greater understanding of the current practices of cyclists as well as their rationale for the use of specific practices. Identification of practices employed combined with current scientific evidence of the efficacy; risks and benefits may help change behaviour and influence safe participation in sport.

The questionnaire will include questions on training and race history as well as the use and knowledge of ergogenic aids. No personal information or email addresses will be captured as part of the data. Information obtained from the questionnaires will not be provided to any regulatory body, such as the South African Institute for Drug-Free Sport (SAIDS) and Cycling South Africa. All information is strictly confidential and for statistical purposes only. Please open the link below to access the survey:

http://fluidsurveys.com/surveys/ergogenic_aids/copy-the-use-of-ergogenic-aids-by-cyclists/langeng/

This study is being supervised by Dr Theresa Burgess of the division of Physiotherapy, University of Cape Town as well as Professor Mike Lambert and Professor Andrew Bosch, from the Sports Science Institute of South Africa.

If you have any questions about the study please feel free to contact any of the individuals listed below.

Researcher:	Ms Ashleigh Hansen	0795281588; ash_hansen10@hotmail.com
Supervisor:	Dr Theresa Burgess	theresa.burgess@uct.ac.za
Co-Supervisors:	Professor Mike Lambert	mike.lambert@uct.ac.za
	Professor Andrew Bosch	andrew.bosch@uct.ac.za

If you have any concerns or questions regarding your rights or welfare as a research participant, please contact Professor Marc Blockman (Chairperson, Faculty of Health Sciences Research and Ethics Committee) on 021 406 6492 or marc.blockman@uct.ac.za.

Yours kindly

Ashleigh Hansen

(Bsc. Physiotheraphy UCT)

APPENDIX III

The use of ergogenic aids in cyclists*

IN ORDER TO QUALIFY FOR PARTICIPATION YOU MUST:

Please indicate for which criteria you qualify for below.

-You can tick more than one box.

-Competitive cycling was defined according to the following race times; (i) Cape Argus Pick 'n Pay Cycle Tour (109 km): male-sub 3h15m, female-sub 3h30m, (ii) Momentum 94.7 Cycle Challenge (94.7 km): male-sub 2h45m, female- sub 3h00m, and/or (iii) Amashova Durban Classic (106 km): male-sub 3h00m, female- sub 3h15.

☐ Have been cycling competitively for at least two years

☐ Currently cycle a minimum of 80 km per week

☐ Cycle for at least 6 months out of the year

☐ Have participated in at least 3 cycle races/events in the last 6 months

☐ N/A

SECTION A

DEMOGRAPHIC DATA

Please answer the questions below.

GENDER ○ Male

○ Female

AGE (years) _____

HEIGHT (m) _____

WEIGHT (kg) _____

HIGHEST LEVEL OF EDUCATION ○ Grade 10

○ Grade 11

○ Grade 12 (Matric)

*This is originally an online questionnaire, which has subsequently been converted to a word document format, for presentation in this dissertation.

- ○ Diploma
- ○ Undergraduate
- ○ Honours
- ○ Masters
- ○ PhD

MEDICAL SCREENING

Do you suffer from any of the following conditions?

-Please tick the appropriate box/es below.

- ☐ Diabetes Mellitus
- ☐ Any metabolic disorder (please specify) _____
- ☐ An eating disorder
- ☐ N/A

SECTION B

TRAINING AND RACE HISTORY

Please indicate which type of event/s you participate in?

-You can tick more than one box below.

- ☐ Road
- ☐ Mountain (MTB)
- ☐ Track
- ☐ Time trial

Which is your preferred event?-Choose from the drop down list.

- ○ Road
- ○ MTB
- ○ Track
- ○ Time trial

Please COMPLETE the relevant questions below as applicable over the last 12 week period.

Are you currently cycling competitively?

Competitive cycling was defined according to the following race times; (i) Cape Argus Pick 'n Pay Cycle Tour (109 km): male-sub 3h15m, female-sub 3h30m, (ii) Momentum 94.7 Cycle Challenge (94.7 km): male-sub 2h45m, female- sub 3h00m, and/or (iii) Amashova Durban Classic (106 km): male-sub 3h00m, female- sub 3h15.

- ○ Yes
- ○ No

How many years you have been cycling competitively?

_____

In which year did you start competitive endurance cycling?

_____

How many times on average do you cycle per week? (looking at the last 12 weeks)

_____

How many hours on average do you cycle per week? (looking at the last 12 weeks)

_____

How many kilometers (km) on average do you cycle per week? (looking at the last 12 weeks)

- ○ 81-100
- ○ 101-120
- ○ 121-140
- ○ 141-160
- ○ 161-180
- ○ 181-200
- ○ 201-220
- ○ 221-240
- ○ 241-260
- ○ 261-280

... 1 additional choices hidden (281-320) ...

- ○ 321-340
- ○ 341-360
- ○ 361-380
- ○ 381-400

○ 401-420

○ 421-440

○ 441-460

○ 461-480

○ 481-500

○ >500

How many of your rides per week would you classify as hard rides? (>75% heart rate maximum)

_____

How many (1 day) races have you completed, in the last 12 weeks?

_____

How many multi-stage/day events have you completed in the last 12 weeks?

_____

What is your best race time for the following races and when did you achieve this time (year)?

	Time (hours; minutes)	Year
Cape Argus Pick ‘n Pay Cycle Tour	_____	_____
Momentum 94.7 Cycle Challenge	_____	_____
Amashova Durban Classic	_____	_____
Double Century	_____	_____
Reeds Chevrolet Ninty Niner	_____	_____
Die Burger	_____	_____
Franchhoek valley Delta Trap	_____	_____
Pick 'n Pay Mountain Bike Challenge	_____	_____
Napier Patasfees MTB (60 km)	_____	_____
MTN National Marathon series #3 Tulbagh	_____	_____
MTN National Marathon series #5 Wellington gravel travel	_____	_____

How many days after a race (80 km to 100 km) would you resume normal training?

○ 1

○ 2-3

○ 4-5

○ 6-7

○ 8-10

○ >11

How many days after a multi-stage/day event would you resume normal training?

- ○ 1
- ○ 2-3
- ○ 4-5
- ○ 6-7
- ○ 8-10
- ○ 11-12
- ○ 13-14
- ○ >15
- ○ N/A

FLUID INTAKE

Please answer the questions below.

How would you best describe your fluid intake during an endurance (80 km to 100 km) race/event?

-Please indicate by ticking the box/es below.-You can tick more than one box.

- ☐ Drink to thirst
- ☐ Drink as much as tolerable
- ☐ Drink according to a pre-determined drinking schedule
- ☐ Drink to prevent weight loss
- ☐ Drink a bottle per an hour (750 ml)
- ☐ I do not drink
- ☐ Other: Please specify _____

What percentage of your fluid intake will consist of these beverages during a race/event?

Water

- ○ N/A
- ○ 10%
- ○ 20%
- ○ 30%
- ○ 40%
- ○ 50%
- ○ 60%
- ○ 70%

	○ 80%
	○ 90%
	○ 100%
Sports drinks	○ N/A
	○ 10%
	○ 20%
	○ 30%
	○ 40%
	○ 50%
	○ 60%
	○ 70%
	○ 80%
	○ 90%
	○ 100%
Coke	○ N/A
	○ 10%
	○ 20%
	○ 30%
	○ 40%
	○ 50%
	○ 60%
	○ 70%
	○ 80%
	○ 90%
	○ 100%
Other	○ N/A
	○ 10%
	○ 20%
	○ 30%
	○ 40%
	○ 50%
	○ 60%

- ○ 70%
- ○ 80%
- ○ 90%
- ○ 100%

What is your preferred drink of choice the hour leading up to a race/event?

- ○ Water
- ○ Sports drink
- ○ Coke
- ○ Other
- ○ N/A

What is your estimated total fluid intake during a race/event (80 km to 100 km)?

- ○ 100 ml-200 ml
- ○ 201 ml-300 ml
- ○ 301 ml-400 ml
- ○ 401 ml-500 ml
- ○ 501 ml-600 ml
- ○ 601 ml-700ml
- ○ 701 ml-800 ml
- ○ 801 ml-900 ml
- ○ 901 ml-1000 ml
- ○ 1.1 L-1.5 L
- ○ 1.6 L-2 L
- ○ >2.1 L

What is your drink of choice during a race/event (80 km to 100 km)?

- ○ Water
- ○ Sports drink
- ○ Coke
- ○ Other
- ○ N/A

What is your estimated total fluid intake after a race?

30-minutes
- ○ 100 ml-200 ml
- ○ 201 ml-300 ml

- ○ 301 ml-400 ml
- ○ 401 ml-500 ml
- ○ 501 ml-600 ml
- ○ 601 ml-700 ml
- ○ 701 ml-800 ml
- ○ 801 ml-900 ml
- ○ 901 ml-1000 ml
- ○ 1.1 L-1.5 L
- ○ 1.6 L-2 L
- ○ 2.1 L-2.5 L
- ○ 2.6 L-3 L
- ○ >3 L
- ○ N/A

6-hours

- ○ 100 ml-200 ml
- ○ 201 ml-300 ml
- ○ 301 ml-400 ml
- ○ 401 ml-500 ml
- ○ 501 ml-600 ml
- ○ 601 ml-700 ml
- ○ 701 ml-800 ml
- ○ 801 ml-900 ml
- ○ 901 ml-1000 ml
- ○ 1.1 L-1.5 L
- ○ 1.6 L-2 L
- ○ 2.1 L-2.5 L
- ○ 2.6 L-3 L
- ○ >3 L
- ○ N/A

24-hours

- ○ 100 ml-200 ml
- ○ 201 ml-300 ml
- ○ 301 ml-400 ml
- ○ 401 ml-500 ml

- ○ 501 ml-600 ml
- ○ 601 ml-700 ml
- ○ 701 ml-800 ml
- ○ 801 ml-900 ml
- ○ 901 ml-1000 ml
- ○ 1.1 L-1.5 L
- ○ 1.6 L-2 L
- ○ 2.1L-2.5 L
- ○ 2.6 L-3 L
- ○ >3 L
- ○ N/A

What is your preferred drink of choice after a race?

- ○ Water
- ○ Sports drink
- ○ Coke
- ○ Other
- ○ N/A

Please rank your TOP THREE sources of information below, on their importance on formulating/influencing your use of fluids (Please note that there can only be ONE of each number)

1-being the most influential and 3-being the least influential

	1	2	3
Coach/trainer	○	○	○
Fellow cyclists	○	○	○
Books/magazines	○	○	○
Internet	○	○	○
Adverts	○	○	○
Self-experimentation	○	○	○
Research articles	○	○	○
Other	○	○	○

If you selected other in the above question: please specify below.

SECTION C

"ERGOGENIC AIDS"

PERFORMANCE AND RECOVERY PRODUCTS

Ergogenic aids are any products or means of increasing or improving performance and recovery in sport. Athletes frequently use a variety of products to help improve their performance. Examples may include: caffeine, carbo-loading, specific drinks (Energade, Cytomax, PVM, Powerade, USN, Coca-Cola, etc.), vitamin supplementation (injections or tablets), nutritional supplementation (whey protein), blood doping, growth hormone, creatine, anabolic steroids, cortisone and gels. We would like to determine what products South African cyclists are ingesting or using; when they are doing so, and how they believe it works for them. The study is purely for research purposes and statistics. We would like to re-iterate that information obtained from the questionnaires will not be provided to any regulatory body, such as SAIDS and Cycling South Africa.

PLEASE ANSWER THE QUESTIONS BELOW AS CURRENTLY APPLICABLE TO YOU OVER THE LAST 12 WEEKS.

Do you use performance or recovery products to improve your cycling?

- ○ Yes
- ○ No

Which performance and recovery products do you use? -Please indicate by ticking the box/es below.

-You can tick more than one box.

- ☐ Caffeine
- ☐ Blood transfusions
- ☐ Creatine
- ☐ Vitamin B
- ☐ Sports drinks/gels
- ☐ Amino acids
- ☐ Erythropoietin (EPO)
- ☐ Anabolic steroids
- ☐ Nutritional: carbo-loading and or protein
- ☐ Anti-inflammatories (NSAIDs) (e.g. Voltaren)

- ☐ Analgesics (e.g. Paracetemol)
- ☐ Electrolytes
- ☐ Growth hormone
- ☐ Corticosteroids (cortisone)
- ☐ Other: Please specify _____
- ☐ N/A

Performance and recovery product:

CAFFEINE

Please answer the questions below regarding your use of caffeine.

When do you use caffeine OR a caffeine containing substance as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

- ☐ Before every training ride (1-2 hours)
- ☐ Only if the training ride is going to be particularly long or hard
- ☐ Before every race/event (1-2 hours)
- ☐ Only if the race/event is going to be particularly long or hard
- ☐ Every day no matter what training or race is planned
- ☐ Only when I am injured
- ☐ Only when I am stiff and tired
- ☐ During training rides
- ☐ During races/events
- ☐ Other: please specify _____

How do you ingest caffeine for the specific purpose of improving performance or recovery? -Please specify the quantity/amount that you take in the text box provided.-You can tick more than one box.

☐ Coffee _____

☐ Capsules _____

☐ Red Bull _____

☐ Chocolate _____

☐ Other: please specify _____

Do you feel caffeine improves your performance?

○ Yes

○ No

In your opinion how do you think caffeine works as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

☐ Increases muscle mass

☐ Increases lean muscle mass

☐ Increases endurance and time to exhaustion/fatigue

☐ Increases strength and power performance

☐ Decreases cellular damage

☐ Decreases stiffness

☐ Unsure

☐ Other: please specify _____

Do you feel that if you did not use caffeine, your performance would deteriorate?

○ Yes

○ No

Please rank your TOP THREE sources of information below, on their importance on formulating/influencing your use of caffeine (Please note that there can only be ONE of each number)

1-being the most influential and 3-being the least influential

	1	2	3
Coach/trainer	○	○	○
Fellow cyclists	○	○	○
Books/magazines	○	○	○

Internet	○	○	○
Adverts	○	○	○
Self-experimentation	○	○	○
Research articles	○	○	○
Other	○	○	○

If you selected other in the above question: please specify below.

Performance and recovery product:

BLOOD TRANSFUSIONS

Please answer the questions below regarding your use of blood doping.

How do you administer blood doping?

☐ Intravenously

☐ Other: please specify _____

How many times a year do you transfuse blood?

○ 1

○ 2

○ 3

○ 4

○ 5

○ 6

○ 7

○ 8

○ 9

○ 10

○ 11

○ 12

○ >13

Do you have help administering this performance and recovery product from either of the following people?-Please indicate by ticking the box/es below.-You can tick more than one box.

- ☐ General Practitioner (GP)
- ☐ A physiotherapist
- ☐ Medical support personal
- ☐ Team mate
- ☐ Other: please specify _____

Do you feel that blood doping improves your performance?

- ○ Yes
- ○ No

How many years have you been blood doping?

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ 6
- ○ 7
- ○ 8
- ○ 9
- ○ 10
- ○ 11
- ○ 12
- ○ 13
- ○ 14
- ○ 15
- ○ 16
- ○ 17
- ○ 18
- ○ 19
- ○ 20
- ○ >21

In your opinion how do you think blood doping works as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

- ☐ Increases muscle mass
- ☐ Increases lean muscle mass
- ☐ Increases endurance and time to exhaustion/fatigue
- ☐ Increases strength and power performance
- ☐ Decreases cellular damage
- ☐ Decreases stiffness
- ☐ Unsure
- ☐ Other: please specify _____

Do you feel that if you did not use blood doping, your performance would deteriorate?

- ○ Yes
- ○ No

Please rank your TOP THREE sources of information below, on their importance on formulating/influencing your use of blood doping (Please note that there can only be ONE of each number) 1-being the most influential and 3-being the least influential

	1	2	3
Coach/trainer	○	○	○
Fellow cyclists	○	○	○
Books/magazines	○	○	○
Internet	○	○	○
Adverts	○	○	○
Self-experimentation	○	○	○
Research articles	○	○	○
Other	○	○	○

If you selected other in the above question: please specify below.

Performance and recovery product:

CREATINE

Please answer the questions below regarding your use of creatine.

When do you use creatine as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

- ☐ Before every training ride (1-2 hours)
- ☐ Only if the training ride is going to be particularly long or hard
- ☐ Before every race/event (1-2 hours)
- ☐ Only if the race/event is going to be particularly long or hard
- ☐ Every day no matter what training or race is planned
- ☐ Only when I am injured
- ☐ Only when I am stiff and tired
- ☐ During training rides
- ☐ During races/events
- ☐ Other: please specify _____

Do you feel creatine improves your performance?

- ○ Yes
- ○ No

In your opinion how do you think creatine works as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

- ☐ Increases muscle mass
- ☐ Increases lean muscle mass
- ☐ Increases endurance and time to exhaustion/fatigue
- ☐ Increases strength and power performance
- ☐ Decreases cellular damage
- ☐ Decreases stiffness
- ☐ Unsure
- ☐ Other: please specify _____

Do you feel that if you did not use creatine, your performance would deteriorate?

- ○ Yes
- ○ No

Please rank your TOP THREE sources of information below, on their importance on formulating/influencing your use of creatine (Please note that there can only be ONE of each number) 1-being the most influential and 3-being the least influential

	1	2	3
Coach/trainer	○	○	○
Fellow cyclists	○	○	○
Books/magazines	○	○	○
Internet	○	○	○
Adverts	○	○	○
Self-experimentation	○	○	○
Research articles	○	○	○
Other	○	○	○

If you selected other in the above question: please specify below.

Performance and recovery product:

VITAMIN B

Please answer the questions below regarding your use of Vitamin B.

When do you use Vitamin B as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

- ☐ Before every training ride (1-2 hours)
- ☐ Only if the training ride is going to be particularly long or hard
- ☐ Before every race/event (1-2 hours)
- ☐ Only if the race/event is going to be particularly long or hard
- ☐ Every day no matter what training or race is planned
- ☐ Only when I am injured
- ☐ Only when I am stiff and tired
- ☐ During training rides
- ☐ During races/events
- ☐ Other: please specify _____

Do you feel Vitamin B improves your performance?

- ○ Yes
- ○ No

In your opinion how do you think Vitamin B works as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

- ☐ Increases muscle mass
- ☐ Increases lean muscle mass
- ☐ Increases endurance and time to exhaustion/fatigue
- ☐ Increases strength and power performance
- ☐ Decreases cellular damage
- ☐ Decreases stiffness
- ☐ Unsure
- ☐ Other: please specify _____

Do you feel that if you did not use Vitamin B, your performance would deteriorate?

- ○ Yes
- ○ No

Please rank your TOP THREE sources of information below, on their importance on formulating/influencing your use of Vitamin B (Please note that there can only be ONE of each number) 1-being the most influential and 3-being the least influential

	1	2	3
Coach/trainer	○	○	○
Fellow cyclists	○	○	○
Books/magazines	○	○	○
Internet	○	○	○
Adverts	○	○	○
Self-experimentation	○	○	○
Research articles	○	○	○
Other	○	○	○

If you selected other in the above question: please specify below.

Performance and recovery product:

SPORTS DRINKS/GELS

Please answer the questions below regarding your use of sports drinks/gels.

Which product do you use most frequently?

- ○ Sports drinks
- ○ Gels
- ○ Both

When do you use sports drinks/gels as a performance or recovery products?-Please indicate by ticking the box/es below.-You can tick more than one box.

- ☐ Before every training ride (1-2 hours)
- ☐ Only if the training ride is going to be particularly long or hard
- ☐ Before every race/event (1-2 hours)
- ☐ Only if the race/event is going to be particularly long or hard
- ☐ Every day no matter what training or race is planned
- ☐ Only when I am injured

☐ Only when I am stiff and tired

☐ During training rides

☐ During races/events

☐ Other: please specify _____

Do you feel sports drinks/gels improve your performance?

○ Yes

○ No

In your opinion how do you think sports drinks/gel work as performance or recovery products?- Please indicate by ticking the box/es below.-You can tick more than one box.

☐ Increases muscle mass

☐ Increases lean muscle mass

☐ Increases endurance and time to exhaustion/fatigue

☐ Increases strength and power performance

☐ Decreases cellular damage

☐ Decreases stiffness

☐ Unsure

☐ Other: please specify _____

Do you feel that if you did not use sports drinks/gels, your performance would deteriorate?

○ Yes

○ No

Please rank your TOP THREE sources of information below, on their importance on formulating/influencing your use of sports drinks/gels (Please note that there can only be ONE of each number) 1-being the most influential and 3-being the least influential

	1	2	3
Coach/trainer	○	○	○
Fellow cyclists	○	○	○
Books/magazines	○	○	○
Internet	○	○	○
Adverts	○	○	○
Self-experimentation	○	○	○
Research articles	○	○	○
Other	○	○	○

If you selected other in the above question: please specify below.

Performance and recovery product:

AMINO ACIDS (BCAA/WHEY)

Please answer the questions below regarding your use of amino acids.

In what form are you using amino acids?-Please indicate by ticking the box below.

- ☐ Branched Chain Amino Acids (BCAA)
- ☐ Whey
- ☐ BCAA and Whey
- ☐ Other: please specify _____

When do you use amino acids as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

- ☐ Before every training ride (1-2 hours)
- ☐ Only if the training ride is going to be particularly long or hard
- ☐ Before every race/event (1-2 hours)
- ☐ Only if the race/event is going to be particularly long or hard
- ☐ Every day no matter what training or race is planned
- ☐ Only when I am injured
- ☐ Only when I am stiff and tired
- ☐ During training rides
- ☐ During races/events
- ☐ Other: please specify _____

Do you feel amino acids improve your performance?

- ○ Yes
- ○ No

In your opinion how do you think amino acids work as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

- ☐ Increases muscle mass
- ☐ Increases lean muscle mass

☐ Increases endurance and time to exhaustion/fatigue

☐ Increases strength and power performance

☐ Decreases cellular damage

☐ Decreases stiffness

☐ Unsure

☐ Other: please specify _____

Do you feel that if you did not use amino acids, your performance would deteriorate?

○ Yes

○ No

Please rank your TOP THREE sources of information below, on their importance on formulating/influencing your use of amino acids (Please note that there can only be ONE of each number) 1-being the most influential and 3-being the least influential

	1	2	3
Coach/trainer	○	○	○
Fellow cyclists	○	○	○
Books/magazines	○	○	○
Internet	○	○	○
Adverts	○	○	○
Self-experimentation	○	○	○
Research articles	○	○	○
Other	○	○	○

If you selected other in the above question: please specify below.

Performance and recovery product:

ERYTHROPOIETIN (EPO)

Please answer the questions below regarding your use of EPO.

Do you use EPO for....

○ Therapeutic use :please specify _____

○ A performance and recovery aid

If you are using EPO for therapeutic purposes please skip this subsection and move forward to the next relevant subsection. If you are using EPO for performance and recovery purposes please answer the rest of the questions below.

When do you use EPO as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

- ☐ Before every training ride (1-2 hours)
- ☐ Only if the training ride is going to be particularly long or hard
- ☐ Before every race/event (1-2 hours)
- ☐ Only if the race/event is going to be particularly long or hard
- ☐ Every day no matter what training or race is planned
- ☐ Only when I am injured
- ☐ Only when I am stiff and tired
- ☐ During training rides
- ☐ During races/events
- ☐ Other: please specify _____

Do you have help administering this performance and recovery product from either of the following people?-Please indicate by ticking the box/es below.-You can tick more than one box.

- ☐ General Practitioner (GP)
- ☐ A physiotherapist
- ☐ Medical support personal
- ☐ Team mate
- ☐ Other: please specify _____

How many years have you been using EPO?

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ 6
- ○ 7
- ○ 8
- ○ 9

- ○ 10
- ○ 11
- ○ 12
- ○ 13
- ○ 14
- ○ 15
- ○ 16
- ○ 17
- ○ 18
- ○ 19
- ○ 20
- ○ >21

Do you feel that EPO improves your performance?

- ○ Yes
- ○ No

In your opinion how do you think EPO works as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

- ☐ Increases muscle mass
- ☐ Increases lean muscle mass
- ☐ Increases endurance and time to exhaustion/fatigue
- ☐ Increases strength and power performance
- ☐ Decreases cellular damage
- ☐ Decreases stiffness
- ☐ Unsure
- ☐ Other: please specify _____

Do you feel that if you did not use EPO, your performance would deteriorate?

- ○ Yes
- ○ No

Please rank your TOP THREE sources of information below, on their importance on formulating/influencing your use of EPO (Please note that there can only be ONE of each number)

1-being the most influential and 3-being the least influential

	1	2	3
Coach/trainer	○	○	○
Fellow cyclists	○	○	○
Books/magazines	○	○	○
Internet	○	○	○
Adverts	○	○	○
Self-experimentation	○	○	○
Research articles	○	○	○
Other	○	○	○

If you selected other in the above question: please specify below.

Performance and recovery product:

ANABOLIC STEROIDS

Please answer the questions below regarding your use of anabolic steroids.

How many years have you been using anabolic steroids?

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ 6
- ○ 7
- ○ 8
- ○ 9
- ○ 10
- ○ 11

○ 12

○ 13

○ 14

○ 15

○ 16

○ 17

○ 18

○ 19

○ 20

○ >21

When do you use anabolic steroids as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

☐ Before every training ride (1-2 hours)

☐ Only if the training ride is going to be particularly long or hard

☐ Before every race/event (1-2 hours)

☐ Only if the race/event is going to be particularly long or hard

☐ Every day no matter what training or race is planned

☐ Only when I am injured

☐ Only when I am stiff and tired

☐ During training rides

☐ During races/events

☐ Other: please specify _____

Do you feel anabolic steroids improve your performance?

○ Yes

○ No

In your opinion how do you think anabolic steroids work as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

☐ Increases muscle mass

☐ Increases lean muscle mass

☐ Increases endurance and time to exhaustion/fatigue

☐ Increases strength and power performance

☐ Decreases cellular damage

☐ Decreases stiffness

☐ Unsure

☐ Other: please specify _____

Do you feel that if you did not use anabolic steroids, your performance would deteriorate?

○ Yes

○ No

Please rank your TOP THREE sources of information below, on their importance on formulating/influencing your use of anabolic steroids (Please note that there can only be ONE of each number) 1-being the most influential and 3-being the least influential

	1	2	3
Coach/trainer	○	○	○
Fellow cyclists	○	○	○
Books/magazines	○	○	○
Internet	○	○	○
Adverts	○	○	○
Self-experimentation	○	○	○
Research articles	○	○	○
Other	○	○	○

If you selected other in the above question: please specify below.

Performance and recovery product:

NUTRITION: CARBOHYDRATES AND PROTEIN

Do you use carbohydrates as a performance and recovery aid?

○ Yes

○ No

If you ticked YES please answer all the questions below. If you ticked NO please click the NEXT button at the bottom of the page.

Carbohydrates

When do you use carbohydrates as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

☐ Before every training ride (1-2 hours)

☐ Only if the training ride is going to be particularly long or hard

☐ Before every race/event (1-2 hours)

☐ Only if the race/event is going to be particularly long or hard

☐ Every day no matter what training or race is planned

☐ Only when I am injured

☐ Only when I am stiff and tired

☐ During training rides

☐ During races/events

☐ Other: please specify _____

How soon after training or a race do you start ingesting carbohydrates?

☐ Within 30 minutes of finishing

☐ Within 2-4 hours of finishing

☐ >6 hours of finishing

☐ Within no specific time period

☐ I don't ingest carbohydrates after training or a race

Do you try to eat/drink a specific amount of carbohydrates calculated according to your body mass per day, whilst training?

○ Yes

○ No

If you ticked YES in the above question, then what formula are you using and/or how many extra grams of carbohydrates are you ingesting?

What form of carbohydrates are you ingesting?-Please indicate by ticking the box/es below.-You can tick more than one box.

☐ Refined (sports drinks/sweets/coke/sugars)

☐ Nutrient dense (pasta/rice/potato/bread)

☐ Supplementation (powder)

☐ Other: please specify _____

If you ticked REFINED carbohydrates in the above question, then please indicate which product type you use most.-Please indicate by ticking the box/es below.-You can tick more than one box.

☐ Sports drinks (Energade/Powerade/Game)

☐ Soft drinks (Coke)

☐ Sweets (Jelly babies)

☐ Gels

☐ Sports bars (energy bars/Jungle oats bar)

☐ Other: please specify _____

If you ticked NUTRIENT DENSE carbohydrates in the above question, then please indicate which product type you use most.-Please indicate by ticking the box/es below.-You can tick more than one box.

☐ Bread

☐ Cereal

☐ Pasta/potato

☐ Rice

☐ Fruit

☐ Other: please specify _____

Protein

Do you use protein as a performance and recovery aid?

○ Yes

○ No

If you ticked YES please answer all the questions below. If you ticked NO please click the NEXT button at the bottom of the page

When do you use protein as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

☐ Before every training ride (1-2 hours)

☐ Only if the training ride is going to be particularly long or hard

☐ Before every race/event (1-2 hours)

☐ Only if the race/event is going to be particularly long or hard

☐ Every day no matter what training or race is planned

☐ Only when I am injured

☐ Only when I am stiff and tired

☐ During training rides

☐ During races/events

☐ Other: please specify _____

How soon after training or a race do you start ingesting protein? (with or without carbohydrates)

☐ Within 30 minutes of finishing

☐ Within 2-4 hours of finishing

☐ >6 hours of finishing

☐ Within no specific time period

☐ I don't ingest protein after training or a race

Do you try to eat/drink a specific amount of protein calculated according to your body mass per day, whilst training?

○ Yes

○ No

If you ticked YES in the above question, then what formula are you using and/or how many extra grams of protein are you ingesting?

What form of protein are you ingesting?-Please indicate by ticking the box/es below.-You can tick more than one box.

☐ Liquid (milk/meal replacement powder)

☐ Lean protein (chicken/meat/eggs/fish)

☐ Body building protein powder

☐ Other: please specify _____

If you ticked LIQUID protein in the above question, then please indicate which product type you use most? -Please indicate by ticking the box/es below.-You can tick more than one box.

☐ Milk

☐ Liquid meal replacement

☐ Body building protein powder

☐ Skim milk powder

☐ Other: please specify _____

If you ticked LEAN protein in the above question, then please indicate which product type you use most. -Please indicate by ticking the box/es below.-You can tick more than one box.

☐ Skinless chicken

☐ Fish

☐ Eggs

☐ Low fat yogurt

☐ Other: please specify

☐ _____

How would you best describe your preparation (5 days prior) leading up to a race?-Please indicate by ticking the box/es below.-You can tick more than one box.

☐ Increased water intake 3 to 5 days prior to the race/event

☐ Change to a high carbohydrate diet 3 to 5 days prior to the race/event

☐ Carbo-load the night before the race/event

☐ I do not change anything

☐ Other: please specify _____

Do you feel nutrition (carbohydrates and/or protein) improves your performance?

○ Yes

○ No

In your opinion how do you think nutrition (carbohydrates and/or protein) works as a performance or recovery product? -Please indicate by ticking the box/es below.-You can tick more than one box.

- ☐ Increases muscle mass
- ☐ Increases lean muscle mass
- ☐ Increases endurance and time to exhaustion/fatigue
- ☐ Increases strength and power performance
- ☐ Decreases cellular damage
- ☐ Decreases stiffness
- ☐ Unsure
- ☐ Other: please specify _____

Do you feel that if you did not use nutrition (carbohydrates and/or protein), your performance would deteriorate?

- ○ Yes
- ○ No

Please rank your TOP THREE sources of information below, on their importance on formulating/influencing your use of nutrition (carbohydrates and/or protein) (Please note that there can only be ONE of each number) 1-being the most influential and 3-being the least influential

	1	2	3
Coach/trainer	○	○	○
Fellow cyclists	○	○	○
Books/magazines	○	○	○
Internet	○	○	○
Adverts	○	○	○
Self-experimentation	○	○	○
Research articles	○	○	○
Other	○	○	○

If you selected other in the above question: please specify below.

Performance and recovery product:

NSAIDs (e.g VOLTAREN)

Please answer the questions below regarding your use of NSAIDs.

How do you administer your NSAIDs?

☐ Intravenously

☐ Orally

☐ Other: please specify _____

When do you use NSAIDs as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

☐ Before every training ride (1-2 hours)

☐ Only if the training ride is going to be particularly long or hard

☐ Before every race/event (1-2 hours)

☐ Only if the race/event is going to be particularly long or hard

☐ Every day no matter what training or race is planned

☐ Only when I am injured

☐ Only when I am stiff and tired

☐ During training rides

☐ During races/events

☐ Other: please specify _____

If taken orally, on average, how many tablets are you taking per dose?

○ 1

○ 2

○ 3

○ 4

○ 5

○ 6

○ >6

○

If taken orally, on average how many doses are you taking per day?

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ 6
- ○ >6
- ○

If taken orally, on average how many days will you continue to take NSAIDs for?

- ○ 1 day
- ○ 2-3 days
- ○ One week
- ○ As long as I feel I need too
- ○ 5
- ○ 6

Do you feel NSAIDs improve your performance?

- ○ Yes
- ○ No

In your opinion how do you think NSAIDs works as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

- ☐ Increases muscle mass
- ☐ Increases lean muscle mass
- ☐ Increases endurance and time to exhaustion/fatigue
- ☐ Increases strength and power performance
- ☐ Decreases cellular damage
- ☐ Decreases stiffness
- ☐ Unsure
- ☐ Other: please specify _____

Do you feel that if you did not use NSAIDs, your performance would deteriorate?

○ Yes

○ No

Please rank your TOP THREE sources of information below, on their importance on formulating/influencing your use of NSAIDs (Please note that there can only be ONE of each number)

1-being the most influential and 3-being the least influential

	1	2	3
Coach/trainer	○	○	○
Fellow cyclists	○	○	○
Books/magazines	○	○	○
Internet	○	○	○
Adverts	○	○	○
Self-experimentation	○	○	○
Research articles	○	○	○
Other	○	○	○

If you selected other in the above question: please specify below.

Performance and recovery product:

Analgesics “pain killers” (e.g PARACETAMOL)

Please answer the questions below regarding your use of pain killers.

When do you use pain killers as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

☐ Before every training ride (1-2 hours)

☐ Only if the training ride is going to be particularly long or hard

☐ Before every race/event (1-2 hours)

☐ Only if the race/event is going to be particularly long or hard

☐ Every day no matter what training or race is planned

☐ Only when I am injured

☐ Only when I am stiff and tired

☐ During training rides

☐ During races/events

☐ Other: please specify _____

On average, how many tablets are you taking per dose?

○ 1

○ 2

○ 3

○ 4

○ 5

○ 6

○ >6

On average how many doses are you taking per day?

○ 1

○ 2

○ 3

○ 4

○ 5

○ 6

○ >6

On average how many days will you continue to take pain killers for?

○ 1 day

○ 2-3 days

○ One week

○ As long as I feel I need too

○ 5

○ 6

Do you feel pain killers improve your performance?

○ Yes

○ No

In your opinion how do you think pain killers work as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

- ☐ Increases muscle mass
- ☐ Increases lean muscle mass
- ☐ Increases endurance and time to exhaustion/fatigue
- ☐ Increases strength and power performance
- ☐ Decreases cellular damage
- ☐ Decreases stiffness
- ☐ Unsure
- ☐ Other: please specify _____

Do you feel that if you did not use pain killers, your performance would deteriorate?

- ○ Yes
- ○ No

Please rank your TOP THREE sources of information below, on their importance on formulating/influencing your use of pain killers (Please note that there can only be ONE of each number) 1-being the most influential and 3-being the least influential

	1	2	3
Coach/trainer	○	○	○
Fellow cyclists	○	○	○
Books/magazines	○	○	○
Internet	○	○	○
Adverts	○	○	○
Self-experimentation	○	○	○
Research articles	○	○	○
Other	○	○	○

If you selected other in the above question: please specify below.

Performance and recovery product:

ELECTROLYTES (e.g REHYDRATE)

Please answer the questions below regarding your use of electrolytes.

When do you use electrolytes as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

- ☐ Before every training ride (1-2 hours)
- ☐ Only if the training ride is going to be particularly long or hard
- ☐ Before every race/event (1-2 hours)
- ☐ Only if the race/event is going to be particularly long or hard
- ☐ Every day no matter what training or race is planned
- ☐ Only when I am injured
- ☐ Only when I am stiff and tired
- ☐ During training rides
- ☐ During races/events
- ☐ Other: please specify _____

How soon after training or a race do you start ingesting electrolytes?

- ☐ Within 30 minutes of finishing
- ☐ Within 2-4 hours of finishing
- ☐ >6 hours of finishing
- ☐ Within no specific time period
- ☐ I don't ingest electrolytes after training or a race

Do you try to consume a specific amount of electrolytes?

- ○ Yes
- ○ No

If you ticked YES in the above question, then what formula are you using and/or how many ml are you ingesting?

What type of electrolytes are you ingesting? -Please indicate by ticking the box/es below.-You can tick more than one box.

☐ Pre-mixed sports drinks

☐ Mixable powders

☐ Capsules/tablets

☐ Other: please specify _____

Do you feel electrolytes improve your performance?

○ Yes

○ No

In your opinion how do you think electrolytes work as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

☐ Increases muscle mass

☐ Increases lean muscle mass

☐ Increases endurance and time to exhaustion/fatigue

☐ Increases strength and power performance

☐ Decreases cellular damage

☐ Decreases stiffness

☐ Unsure

☐ Other: please specify _____

Do you feel that if you did not use electrolytes, your performance would deteriorate?

○ Yes

○ No

Please rank your TOP THREE sources of information below, on their importance on formulating/influencing your use of electrolytes (Please note that there can only be ONE of each number) 1-being the most influential and 3-being the least influential

	1	2	3
Coach/trainer	○	○	○
Fellow cyclists	○	○	○
Books/magazines	○	○	○
Internet	○	○	○
Adverts	○	○	○
Self-experimentation	○	○	○

Research articles	○	○	○
Other	○	○	○

If you selected other in the above question: please specify below.

Performance and recovery product:

GROWTH HORMONE

Please answer the questions below on your use of growth hormone.

Do you use growth hormone for therapeutic (a diagnosed medical condition) purposes or as a performance and recovery product?

☐ Therapeutic purpose (please specify condition) _____

☐ Performance and recovery product

What type of growth hormone do you use?

How do you administer growth hormone?

☐ Intravenously

☐ Other: please specify _____

Do you have help administering this performance and recovery product from either of the following people?-Please indicate by ticking the box/es below.-You can tick more than one box.

☐ General Practitioner (GP)

☐ A physiotherapist

☐ Medical support personal

☐ Team mate

☐ Other: please specify _____

How many years have you been using growth hormone?

○ 1

○ 2

○ 3

○ 4

○ 5

○ 6

- ○ 7
- ○ 8
- ○ 9
- ○ 10
- ○ 11
- ○ 12
- ○ 13
- ○ 14
- ○ 15
- ○ 16
- ○ 17
- ○ 18
- ○ 19
- ○ 20
- ○ >21

When do you use growth hormone as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

- ☐ Before every training ride (1-2 hours)
- ☐ Only if the training ride is going to be particularly long or hard
- ☐ Before every race/event (1-2 hours)
- ☐ Only if the race/event is going to be particularly long or hard
- ☐ Every day no matter what training or race is planned
- ☐ Only when I am injured
- ☐ Only when I am stiff and tired
- ☐ During training rides
- ☐ During races/events
- ☐ Other: please specify _____

Do you feel that growth hormone improves your performance**?**

- ○ Yes
- ○ No

In your opinion how do you think growth hormone works as a performance or recovery product?- Please indicate by ticking the box/es below.-You can tick more than one box.

- ☐ Increases muscle mass
- ☐ Increases lean muscle mass
- ☐ Increases endurance and time to exhaustion/fatigue
- ☐ Increases strength and power performance
- ☐ Decreases cellular damage
- ☐ Decreases stiffness
- ☐ Unsure
- ☐ Other: please specify _____

Do you feel that if you did not use growth hormone, your performance would deteriorate?

- ○ Yes
- ○ No

Please rank your TOP THREE sources of information below, on their importance on formulating/influencing your use of growth hormone (Please note that there can only be ONE of each number) 1-being the most influential and 3-being the least influential

	1	2	3
Coach/trainer	○	○	○
Fellow cyclists	○	○	○
Books/magazines	○	○	○
Internet	○	○	○
Adverts	○	○	○
Self-experimentation	○	○	○
Research articles	○	○	○
Other	○	○	○

If you selected other in the above question: please specify below.

Performance and recovery product:

CORTICOSTEROIDS (CORTISONE)

Please answer the questions below on your use of cortisone.

Do you use cortisone for therapeutic (a diagnosed medical condition) purposes or as a performance and recovery product?

☐ Therapeutic purpose (please specify condition) _____

☐ Performance and recovery product

How do you administer corticosteroids?

☐ Intravenously

☐ Other: please specify _____

Do you have help administering this performance and recovery product from either of the following people?-Please indicate by ticking the box/es below.-You can tick more than one box.

☐ General Practitioner (GP)

☐ A physiotherapist

☐ Medical support personal

☐ Team mate

☐ Other: please specify _____

How many years have you been using cortisone?

○ 1

○ 2

○ 3

○ 4

○ 5

○ 6

○ 7

○ 8

○ 9

○ 10

○ 11

○ 12

○ 13

- ○ 14
- ○ 15
- ○ 16
- ○ 17
- ○ 18
- ○ 19
- ○ 20
- ○ >21

When do you use cortisone as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

- ☐ Before every training ride (1-2 hours)
- ☐ Only if the training ride is going to be particularly long or hard
- ☐ Before every race/event (1-2 hours)
- ☐ Only if the race/event is going to be particularly long or hard
- ☐ Every day no matter what training or race is planned
- ☐ Only when I am injured
- ☐ Only when I am stiff and tired
- ☐ During training rides
- ☐ During races/events
- ☐ Other: please specify _____

Do you feel that cortisone improve your performance?

- ○ Yes
- ○ No

In your opinion how do you think cortisone work as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

- ☐ Increases muscle mass
- ☐ Increases lean muscle mass
- ☐ Increases endurance and time to exhaustion/fatigue
- ☐ Increases strength and power performance
- ☐ Decreases cellular damage
- ☐ Decreases stiffness
- ☐ Unsure
- ☐ Other: please specify _____

Do you feel that if you did not use cortisone, your performance would deteriorate?

- ○ Yes
- ○ No

Please rank your TOP THREE sources of information below, on their importance on formulating/influencing your use of cortisone (Please note that there can only be ONE of each number) 1-being the most influential and 3-being the least influential

	1	2	3
Coach/trainer	○	○	○
Fellow cyclists	○	○	○
Books/magazines	○	○	○
Internet	○	○	○
Adverts	○	○	○
Self-experimentation	○	○	○
Research articles	○	○	○
Other	○	○	○

If you selected other in the above question: please specify below.

Performance and recovery product:

OTHER (please specify below)

Please answer the questions below.

Performance and recovery product used:

When do you use this product as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

- ☐ Before every training ride (1-2 hours)
- ☐ Only if the training ride is going to be particularly long or hard
- ☐ Before every race/event (1-2 hours)
- ☐ Only if the race/event is going to be particularly long or hard
- ☐ Every day no matter what training or race is planned
- ☐ Only when I am injured
- ☐ Only when I am stiff and tired
- ☐ During training rides
- ☐ During races/events
- ☐ Other: please specify _____

In your opinion how do you think it works as a performance or recovery product?-Please indicate by ticking the box/es below.-You can tick more than one box.

- ☐ Increases muscle mass
- ☐ Increases lean muscle mass
- ☐ Increases endurance and time to exhaustion/fatigue
- ☐ Increases strength and power performance
- ☐ Decreases cellular damage
- ☐ Decreases stiffness
- ☐ Unsure
- ☐ Other: please specify _____

Do you feel that if you did not use it, your performance would deteriorate?

○ Yes

○ No

Please rank your TOP THREE sources of information below, on their importance on formulating/influencing your use of this product (Please note that there can only be ONE of each number) 1-being the most influential and 3-being the least influential

	1	2	3
Coach/trainer	○	○	○
Fellow cyclists	○	○	○
Books/magazines	○	○	○
Internet	○	○	○
Adverts	○	○	○
Self-experimentation	○	○	○
Research articles	○	○	○
Other	○	○	○

If you selected other in the above question: please specify below.

APPENDIX IV

UNIVERSITY OF CAPE TOWN

Faculty of Health Sciences

Department of Health and Rehabilitation Sciences

Divisions of Communication Sciences and Disorders; Nursing and Midwifery; Occupational Therapy; Physiotherapy; Disability Studies

F45 Old Main Building, Groote Schuur Hospital
Observatory, Cape Town, W Cape, 7925
Tel: +27 (0) 21 406 6401/ 6428/ 6628/ 6534
Fax: +27 (0) 21 406 6323

Dear Prospective validator (insert individuals name)

REQUEST FOR ASSISTANCE: VALIDATION OF THE QUESTIONNAIRE TITLED

"USE OF ERGOGENIC AIDS IN CYCLISTS"

I am an MPhil (Sports Physiotherapy) student at the University of Cape Town, and am writing to you to request assistance with the validation of an ergogenic aids questionnaire.

It is well known that athletes seek out ergogenic aids to enhance sporting performance. Ergogenic aids can be defined as "any means of enhancing energy utilisation, including energy production, control, and efficiency". Ergogenic enhancing practices include well acknowledged techniques of carbohydrate loading prior to an event, use of supplements such as creatine, caffeine and multi-vitamins to the use of growth hormone and blood doping.

There is little available literature on the use of ergogenic aids by cyclists. The purpose of this study is to gain a greater understanding of the current practices of cyclists as well as their rationale for the use of specific practices. Identification of practices employed combined with current scientific evidence of the efficacy; risks and benefits can help change behaviour and influence safe participation in sport.

Accordingly, I propose to investigate the use of ergogenic aids by cyclists. The study has been given ethics approval by the University of Cape Town, Faculty of Health Sciences Human Research Ethics Committee (*HREC REF: 225/2012*).

As a recognised medical doctor /dietician/physiotherapist, with expertise in the field of sports and exercise science, I therefore wish to request your assistance with the validation of the content of the questionnaire. Please could you review the questionnaire in order to ensure that the questions are clear and easy to understand, and that the questions adequately assess use and knowledge of ergogenic aids by cyclists.

Your feedback will be valuable and greatly appreciated. I have attached the questionnaire; if possible, please could you return any feedback on or before **20 November 2012**. Please contact me should you have further questions.

My contact details are as follows:

Ashleigh Hansen:

Ash_hansen10@hotmail.com

Mobile: 0795281588

Thank you for your time and supporting research in the field of Sports Physiotherapy.

Kind Regards

Ashleigh Hansen

BSc. Physiotherapy (UCT)

Supervisor: Dr Theresa Burgess theresa.burgess@uct.ac.za

Co-Supervisors: Professor Mike Lambert mike.lambert@uct.ac.za

Professor Andrew Bosch Andrew.Bosch@uct.ac.za

APPENDIX V

UNIVERSITY OF CAPE TOWN

Faculty of Health Sciences
Faculty of Health Sciences Research Ethics Committee
Room E52-24 Groote Schuur Hospital Old Main Building
Observatory 7925
Telephone [021] 406 6338 • **Facsimile** [021] 406 6411
e-mail: sumayah.ariefdien@uct.ac.za

26 June 2012

HREC REF: 255/2012

Miss A Hansen
c/o Dr T Burgess
Health & Rehab Sciences
Physiotherapy
OMB

Dear Miss Hansen

PROJECT TITLE: THE USE OF ERGOGENIC AIDS BY CYCLISTS

Thank you for addressing the issues raised by the committee.

It is a pleasure to inform you that the Ethics Committee has **formally approved** the above-mentioned study.

Approval is granted for one year till the 28 July 2013.

Please submit a progress form, using the standardised Annual Report Form (FHS016), if the study continues beyond the approval period. Please submit a Standard Closure form (FHS010)if the study is completed within the approval period.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please quote the REC. REF in all your correspondence.

Yours sincerely

Signed

PROFESSOR M BLOCKMAN
CHAIRPERSON, HSF HUMAN ETHICS

Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938

This serves to confirm that the University of Cape Town Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-SA),

sAriefdien

APPENDIX VI

Table 3.25 and Table 3.36 show the training history of male and female participants. There was no significant difference between average weekly mileage and male and female participants.

Table 3.25: Average weekly mileage (km) covered by male (n=177) and female (n=30) participants. Data are expressed as number of responses (n) and percentages (%).

Weekly mileage (km)	Male (n=177)	Female (n=30)	Total (n=207)
81-100	55 (26.5%)	12 (5.8%)	67 (32.3%)
101-120	19 (9.1%)	2 (1.0%)	21 (10.1%)
121-140	14 (6.7%)	3 (1.5%)	17 (8.2%)
141-160	15 (7.2%)	3 (1.5%)	18 (8.7%)
161-180	8 (3.8%)	4 (1.9%)	12 (5.8%)
181-200	12 (5.8%)	1 (0.5%)	13 (6.3%)
201-220	14 (6.7%)	2 (1.0%)	16 (7.7%)
221-240	7 (3.4%)	0 (0.0%)	7 (3.4%)
241-260	8 (3.8%)	2 (1.0%)	10 (4.8%)
261-280	2 (1.0%)	0 (0.0%)	2 (1.0%)
281-300	7 (3.4%)	0 (0.0%)	7 (3.4%)
301-320	6 (2.9%)	0 (0.0%)	6 (2.9%)
321-340	2 (1.0%)	0 (0.0%)	2 (1.0%)
341-360	3 (1.4%)	1 (0.5%)	4 (1.9%)
361-380	0 (0.0%)	0 (0.0%)	0 (0.0%)
381-400	2 (1.0%)	0 (0.0%)	2 (1.0%)
401-420	2 (1.0%)	0 (0.0%)	2 (1.0%)
421-440	0 (0.0%)	0 (0.0%)	0 (0.0%)
441-460	0 (0.0%)	0 (0.0%)	0 (0.0%)
461-480	0 (0.0%)	0 (0.0%)	0 (0.0%)
481-500	0 (0.0%)	0 (0.0%)	0 (0.0%)
>500	1 (0.5%)	0 (0.0%)	1 (0.5%)

Table 3.26: Average number of times male (n=177) and female (n=30) participants cycle per week. Data are expressed as number of responses (n) and percentages (%).

	Male (n=177)	**Female (n=30)**	**Total (n=207)**
1	15 (7.3%)	3 (1.5%)	18 (8.8%)
2	23 (11.1%)	4 (1.9%)	27 (13.0%)
3	34 (16.4%)	8 (3.9%)	42 (20.3%)
4	49 (23.6%)	8 (3.9%)	57 (27.5%)
5	34 (16.4%)	5 (2.4%)	39 (18.8%)
6	19 (9.1%)	2 (1.0%)	21 (10.1%)
7	1 (0.5%)	0 (0.0%)	1 (0.5%)
8	0 (0.0%)	0 (0.0%)	0 (0.0%)
9	1 (0.5%)	0 (0.0%)	1 (0.5%)
10	1 (0.5%)	0 (0.0%)	1 (0.5%)

APPENDIX VII

Regression analyses of factors influencing the use of specific ergogenic aids.

a) Sports drinks/gels

There were no significant relationships between the use of sports drinks/gels and the predictor variables analysed in Table 3.27.

Table 3.27: Forward stepwise regression analysis of factors influencing the use of sports drinks/gel (n=188; r=0.067).

Steps	Exp(B)	p-value	95% C.I		Wald
			Lower	Upper	
Constant	10.73	0.003			8.60
Age (years)	0.84	0.76	0.27	2.58	0.09
BMI	0.54	0.28	0.18	1.63	1.19
Education	2.30	0.43	0.29	18.45	0.61
Preferred cycling event	1.70	0.29	0.64	4.57	1.12
Cycle competitively	1.09	0.88	0.34	3.47	0.02
Km.wk^{-1}	0.67	0.53	0.20	2.30	0.40
Frequency per week	0.54	0.30	0.16	1.75	1.07
Recovery days post competition	2.12	0.21	0.66	6.82	1.60

b) Vitamin B

There were no significant relationships between the use of Vitamin B and the predictor variables analysed in Table 3.28.

Table 3.28: Forward stepwise regression analysis of factors influencing the use of Vitamin B (n=55; r=0.109).

Steps	Exp(B)	p-value	95% C.I		Wald
			Lower	Upper	
Constant	0.13	0.001			11.86
Age (years)	1.72	0.14	0.84	3.51	2.22
BMI	1.06	0.87	0.52	2.15	0.03
Education	1.56	0.37	0.59	4.09	0.81
Preferred cycling event	0.63	0.17	0.32	1.22	1.87
Cycle competitively	1.36	0.43	0.64	2.90	0.63
Km.wk^{-1}	1.64	0.26	0.70	3.88	1.29
Frequency per week	1.33	0.48	0.60	2.95	0.50
Recovery days post competition	1.65	0.29	0.65	4.20	1.12

c) NSAIDs

There were no significant relationships between the use of NSAIDs and the predictor variables analysed in Table 3.29.

Table 3.29: Forward stepwise regression analysis of factors influencing the use of NSAIDs (n=30; r=0.070).

Steps	Exp(B)	p-value	95% C.I		Wald
			Lower	Upper	
Constant	0.05	0.00			16.57
Age (years)	1.93	0.13	0.82	4.60	2.26
BMI	0.96	0.92	0.40	2.27	0.01
Education	1.49	0.49	0.49	4.53	0.48
Preferred cycling event	2.18	0.09	0.89	5.35	2.90
Cycle competitively	1.32	0.56	0.52	3.40	0.34
Km.wk^{-1}	0.73	0.57	0.26	2.12	0.33
Frequency per week	1.60	0.36	0.59	4.33	0.86
Recovery days post competition	1.33	0.61	0.45	3.96	0.26